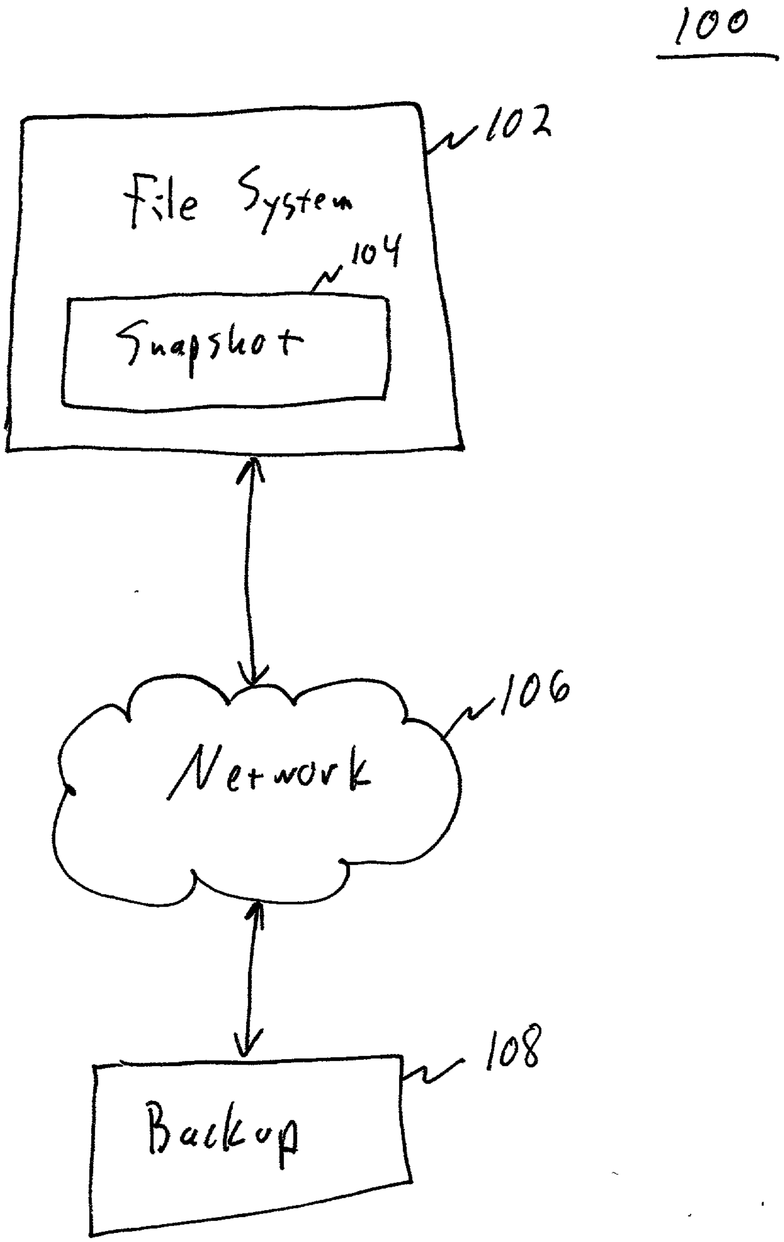


FIG. 1

200

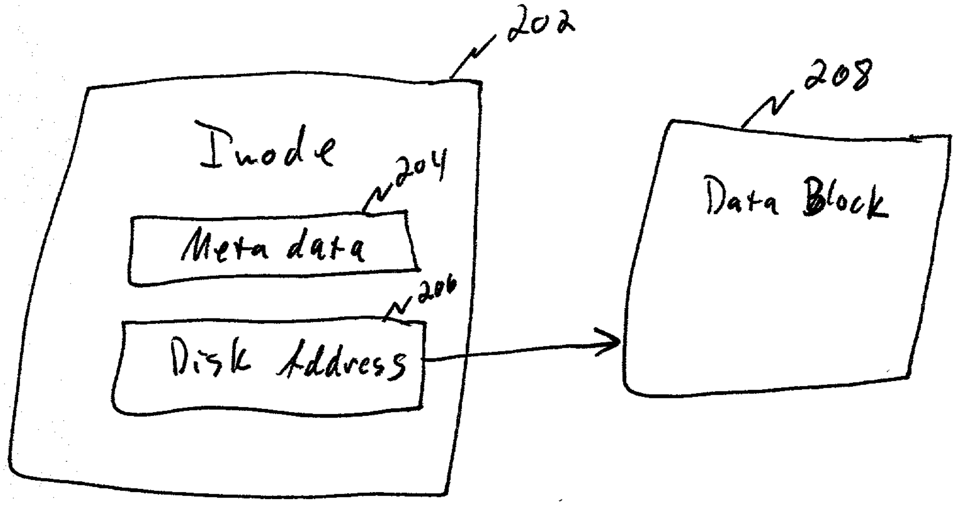


FIG. 2A

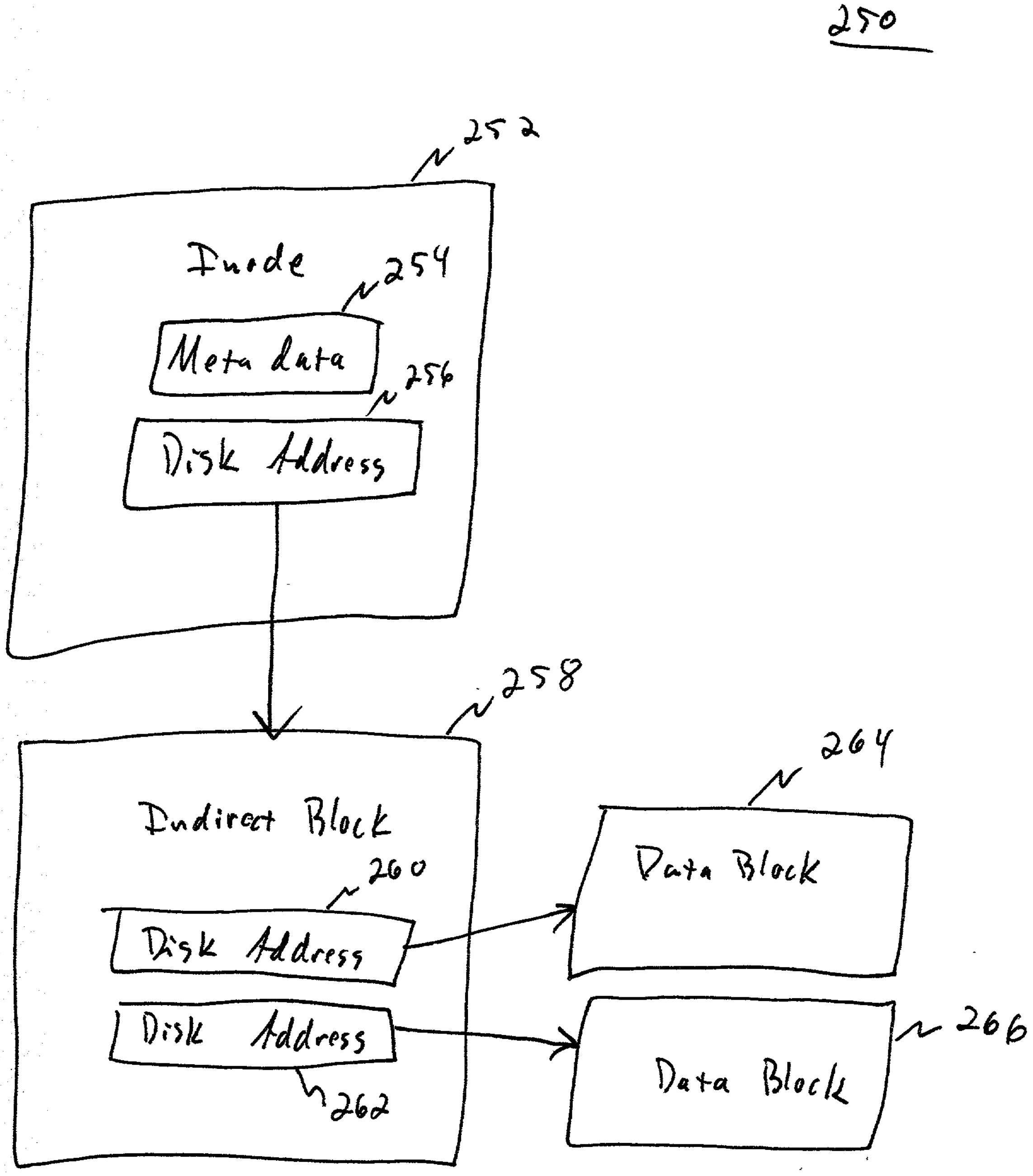

250
252
Inode
254
Meta data
256
Disk Address
258
Indirect Block
260
Disk Address
Disk Address
262
264
Data Block
266
Data Block

FIG. 2B

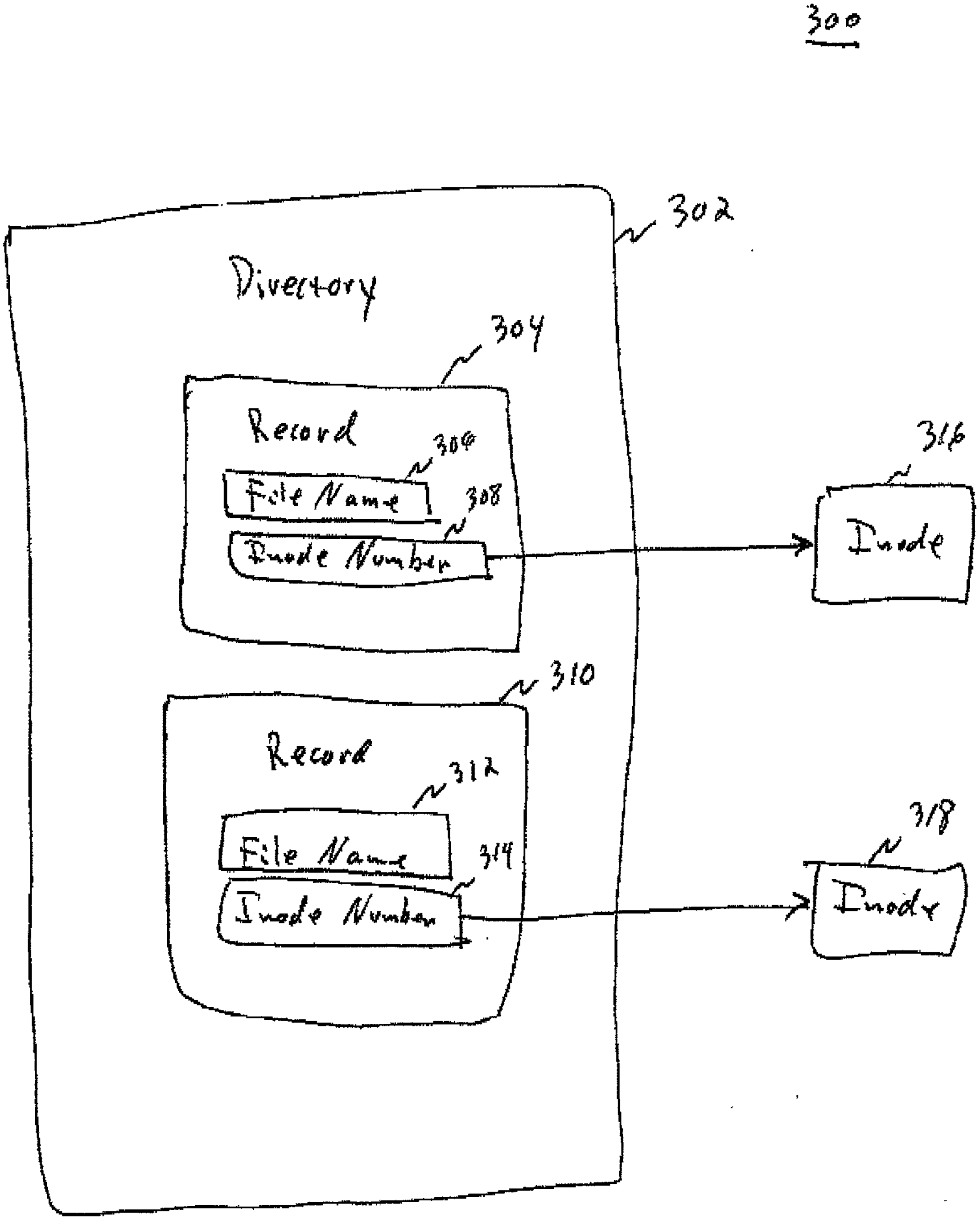

300
302
Directory
304
Record
306
File Name
308
Inode Number
310
Record
312
File Name
314
Inode Number
316
Inode
318
Inode

FIG. 3

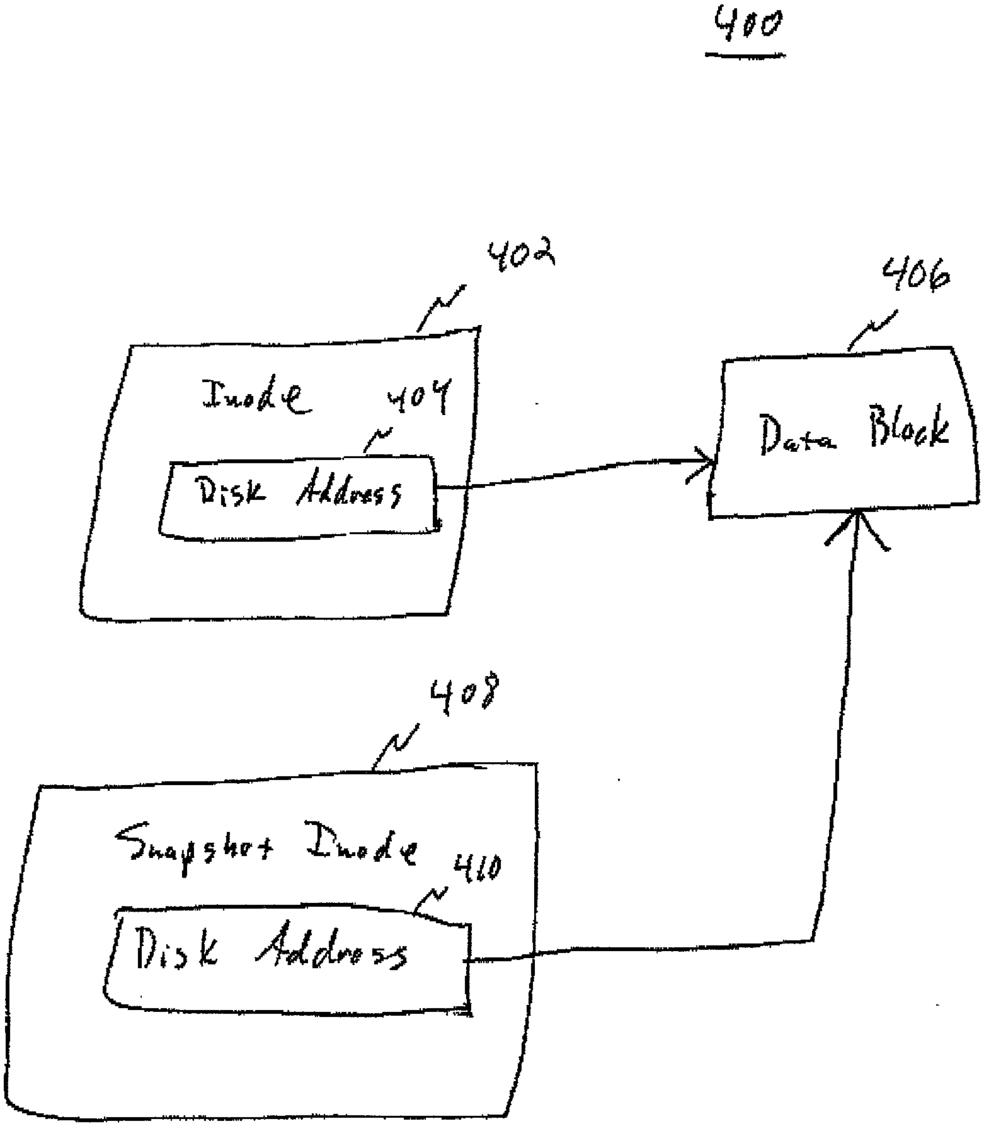
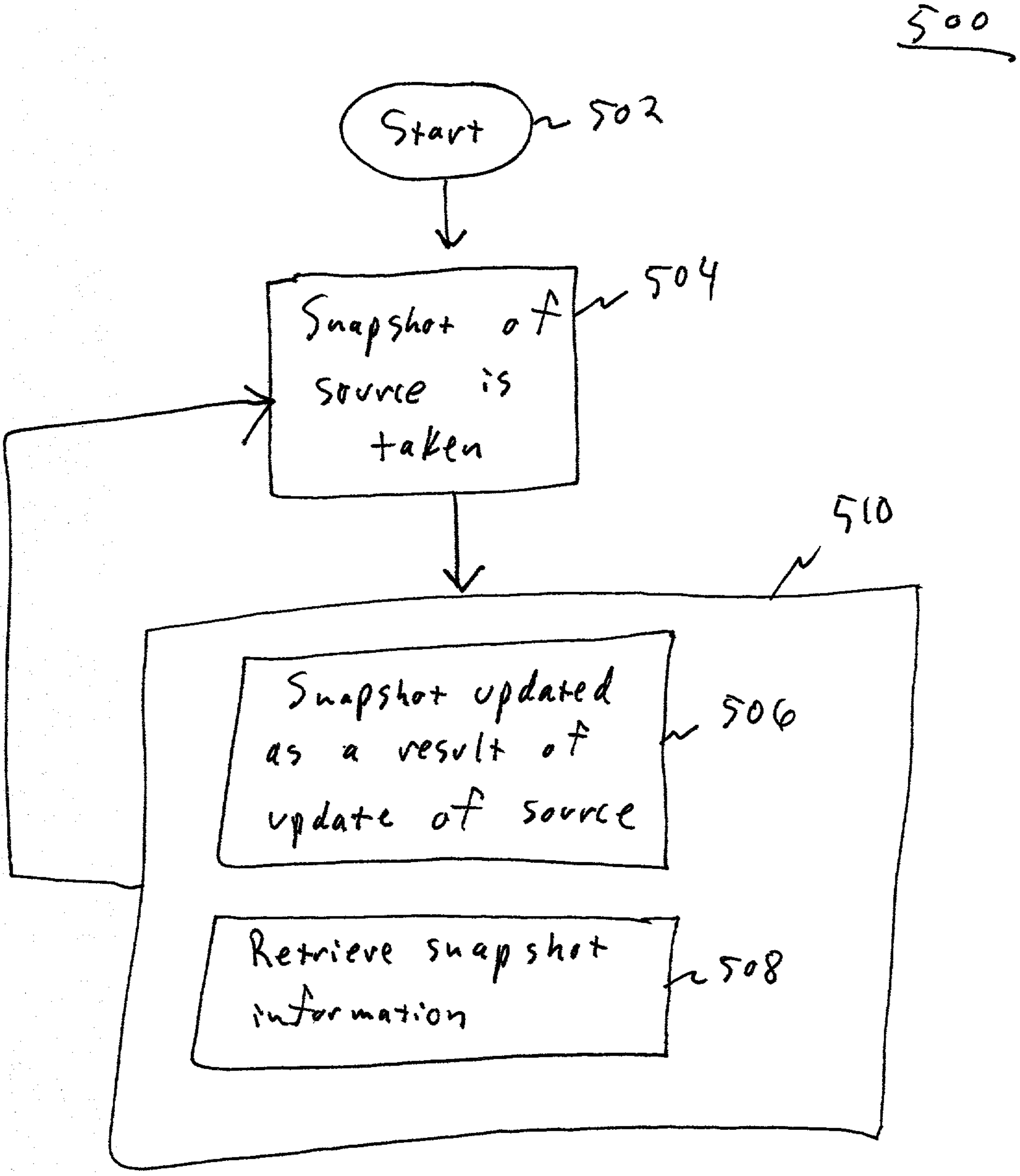

400
402
Inode
404
Disk Address
406
Data Block
408
Snapshot Inode
410
Disk Address

FIG. 4



500
Start
502
Snapshot of source is taken
504
510
Snapshot updated as a result of update of source
506
Retrieve snapshot information
508

FIG. 5

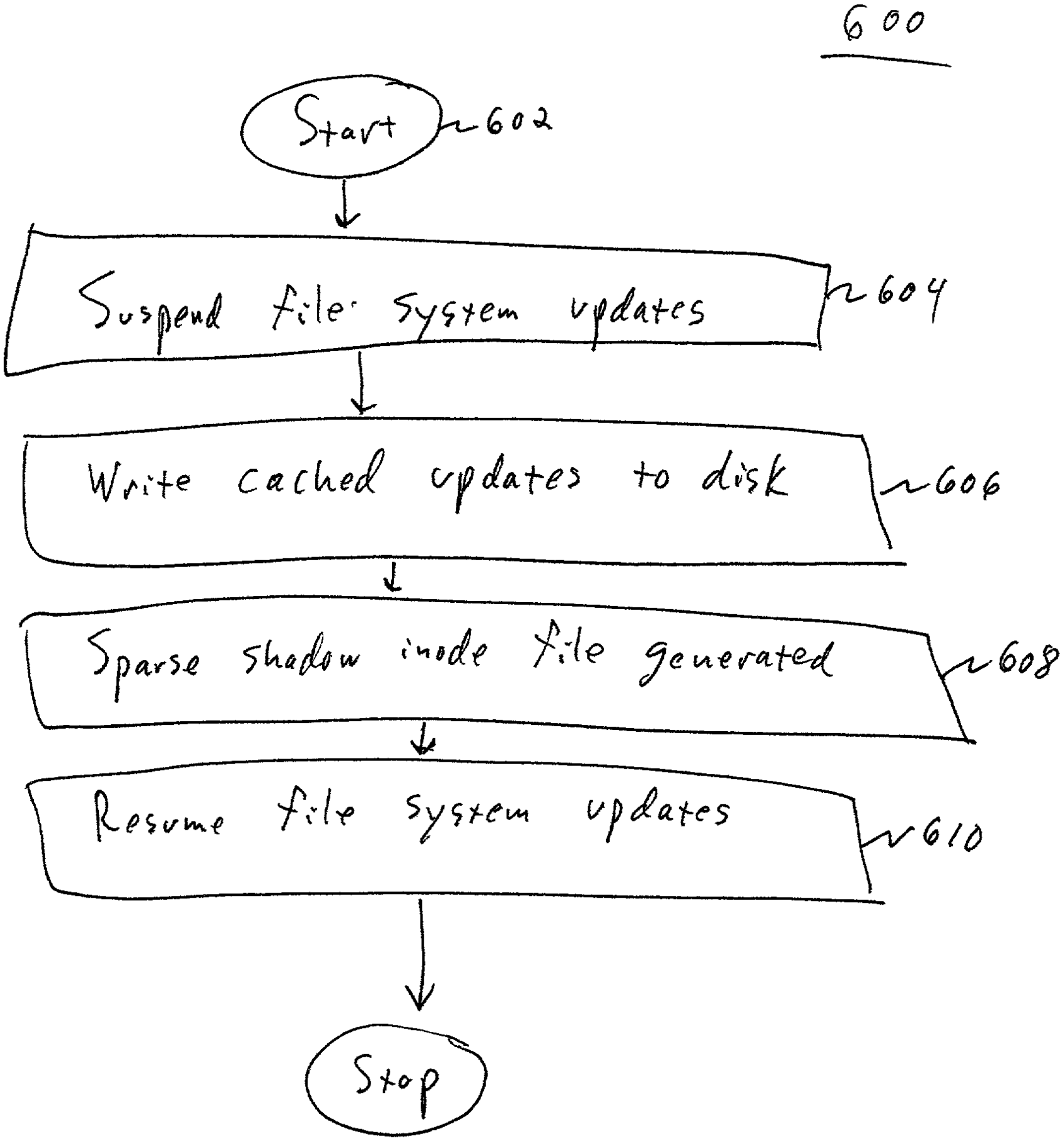

600
Start
602
Suspend file system updates
604
Write cached updates to disk
606
Sparse shadow inode file generated
608
Resume file system updates
610
Stop

FIG. 6A

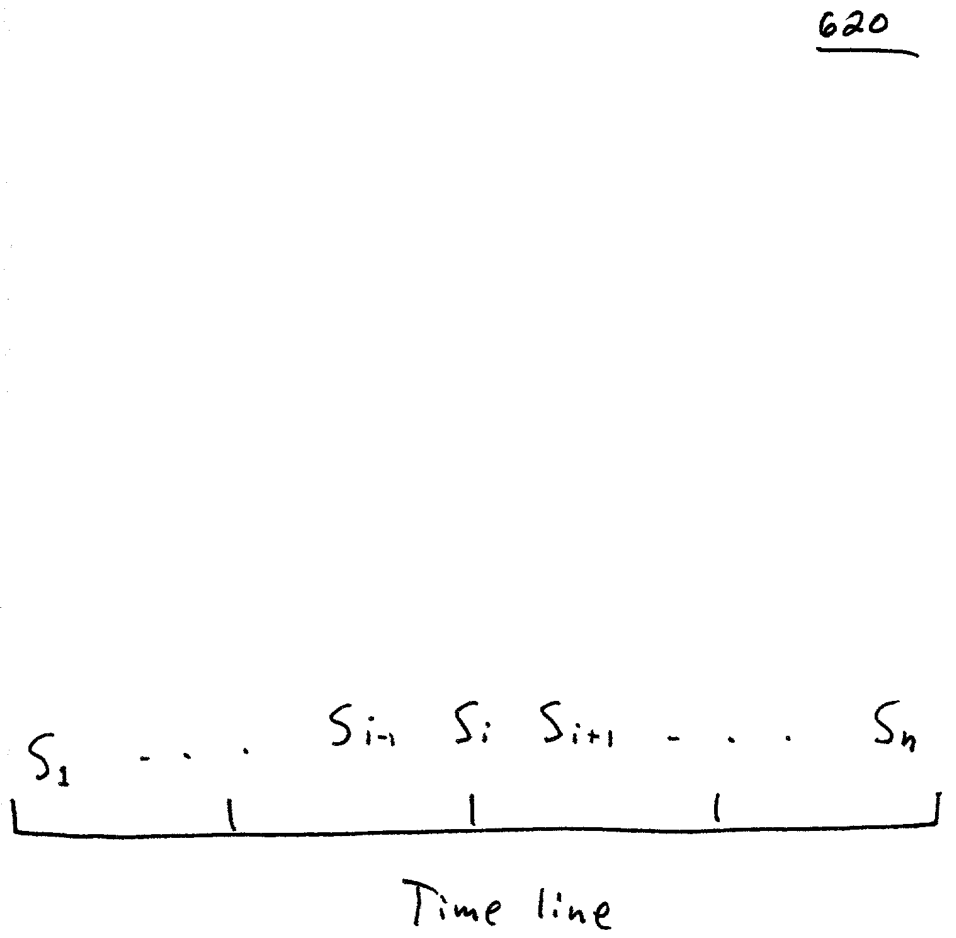


FIG. 6B

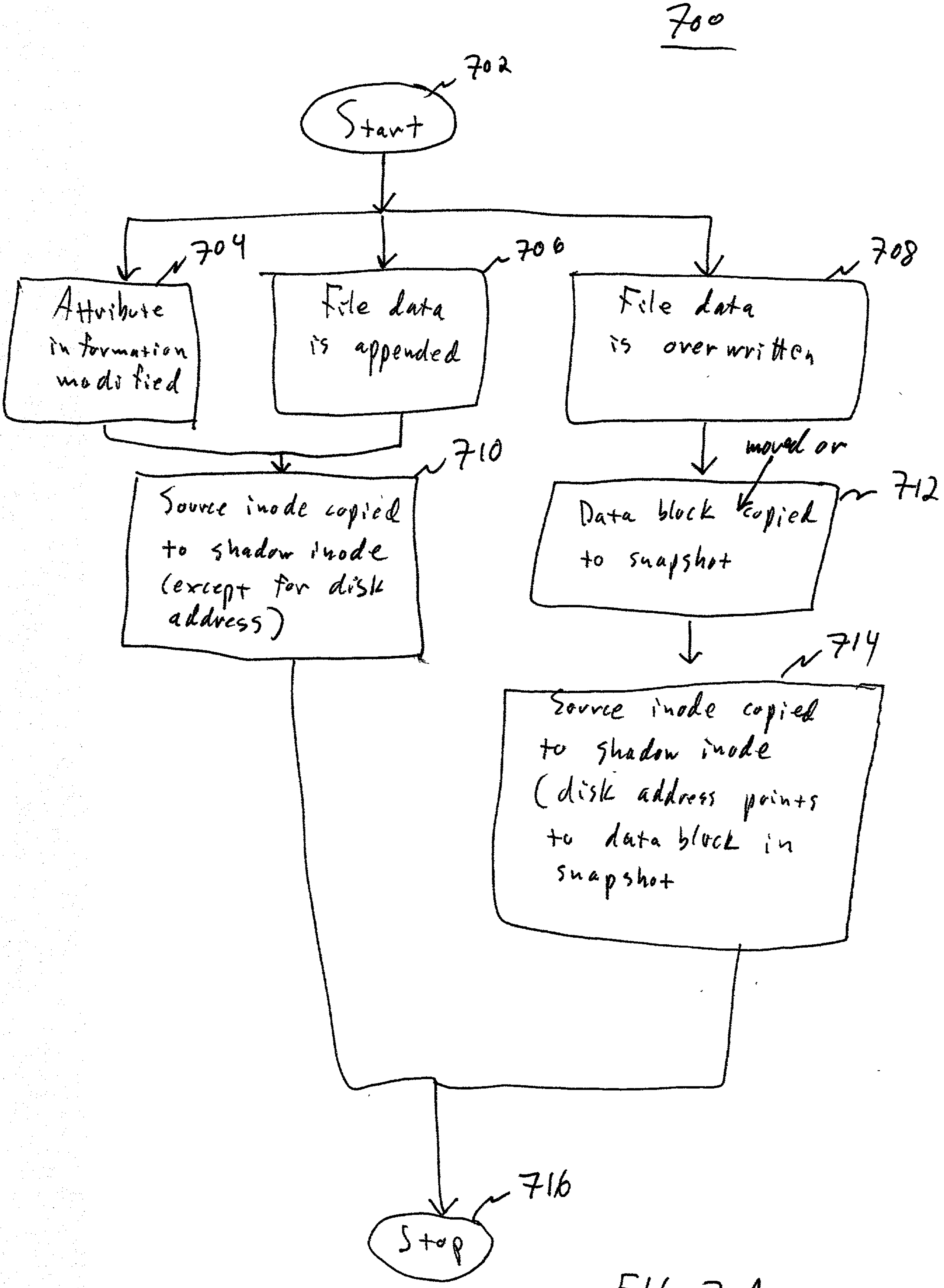

700
702
Start
704
Attribute information modified
706
File data is appended
708
File data is overwritten
710
Source inode copied to shadow inode (except for disk address)
moved or
712
Data block copied to snapshot
714
Source inode copied to shadow inode (disk address points to data block in snapshot
716
Stop

FIG. 7A

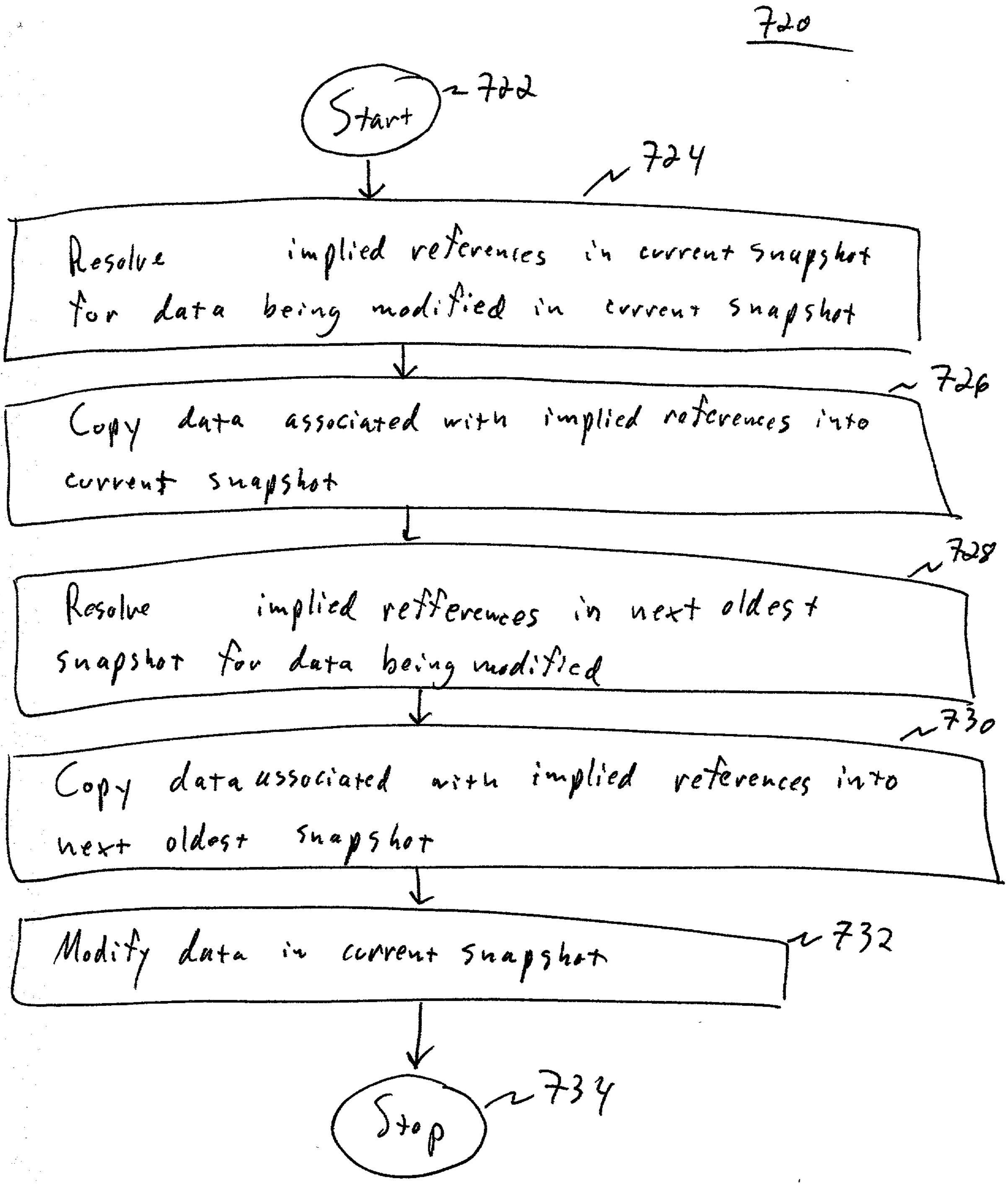

720
Start
722
724
Resolve implied references in current snapshot for data being modified in current snapshot
Copy data associated with implied references into current snapshot
726
Resolve implied refferences in next oldest snapshot for data being modified
728
Copy data associated with implied references into next oldest snapshot
730
Modify data in current snapshot
732
Stop
734

FIG. 7B

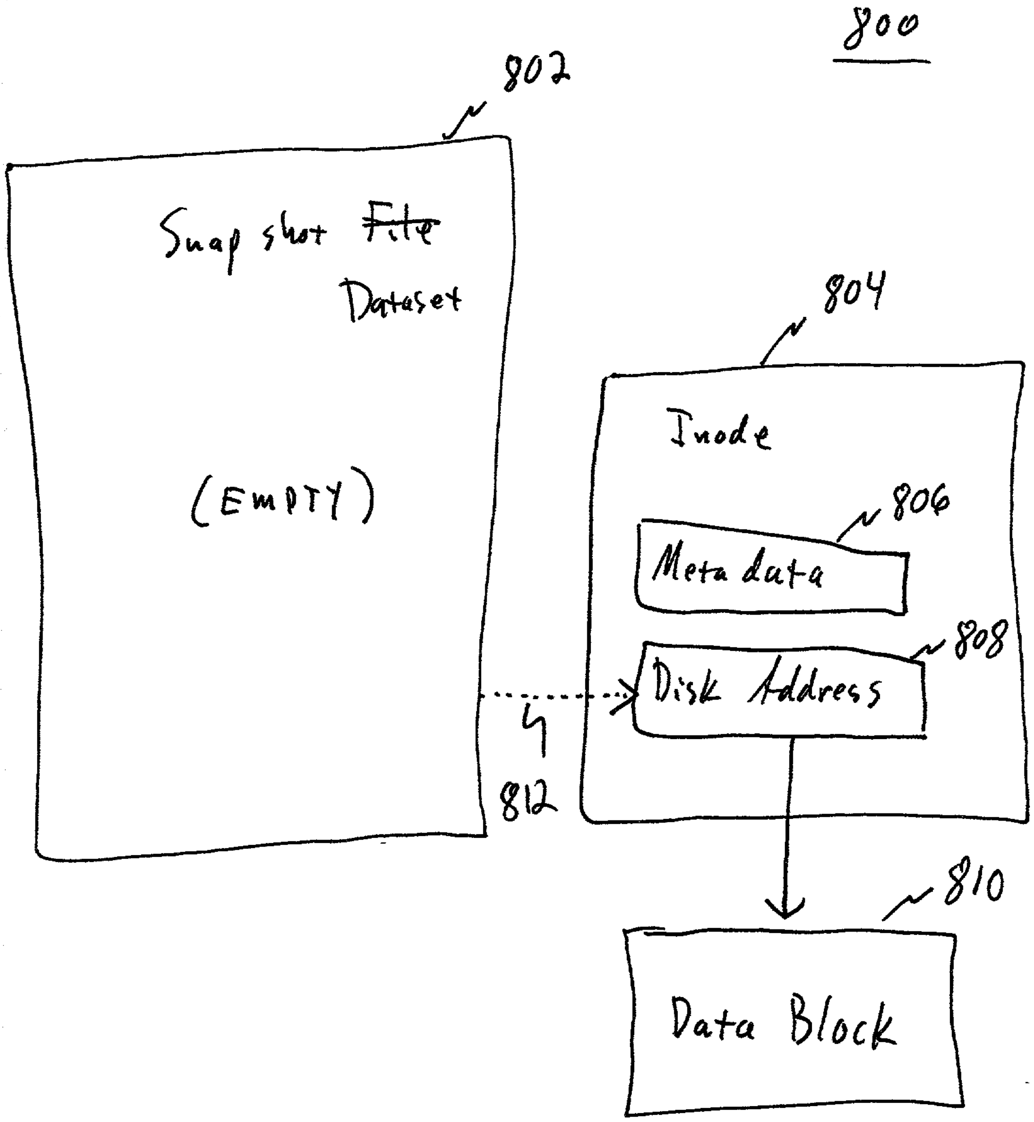

800
802
Snapshot ~~File~~ Dataset
(EMPTY)
804
Inode
806
Metadata
808
Disk Address
812
810
Data Block

FIG. 8A

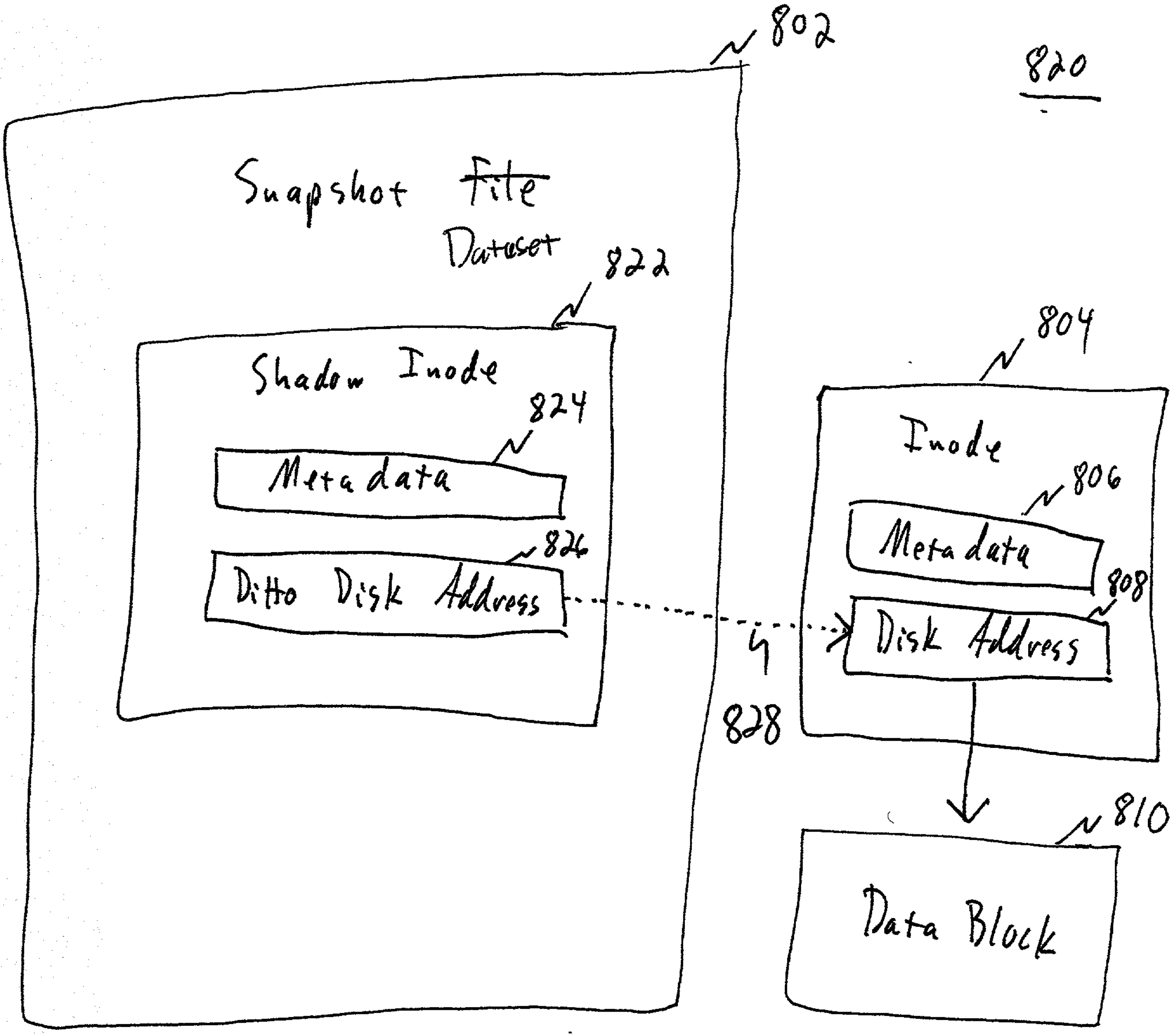

820
802
Snapshot ~~File~~ Dataset
822
Shadow Inode
824
Metadata
826
Ditto Disk Address
828
804
Inode
806
Metadata
808
Disk Address
810
Data Block

FIG. 8B

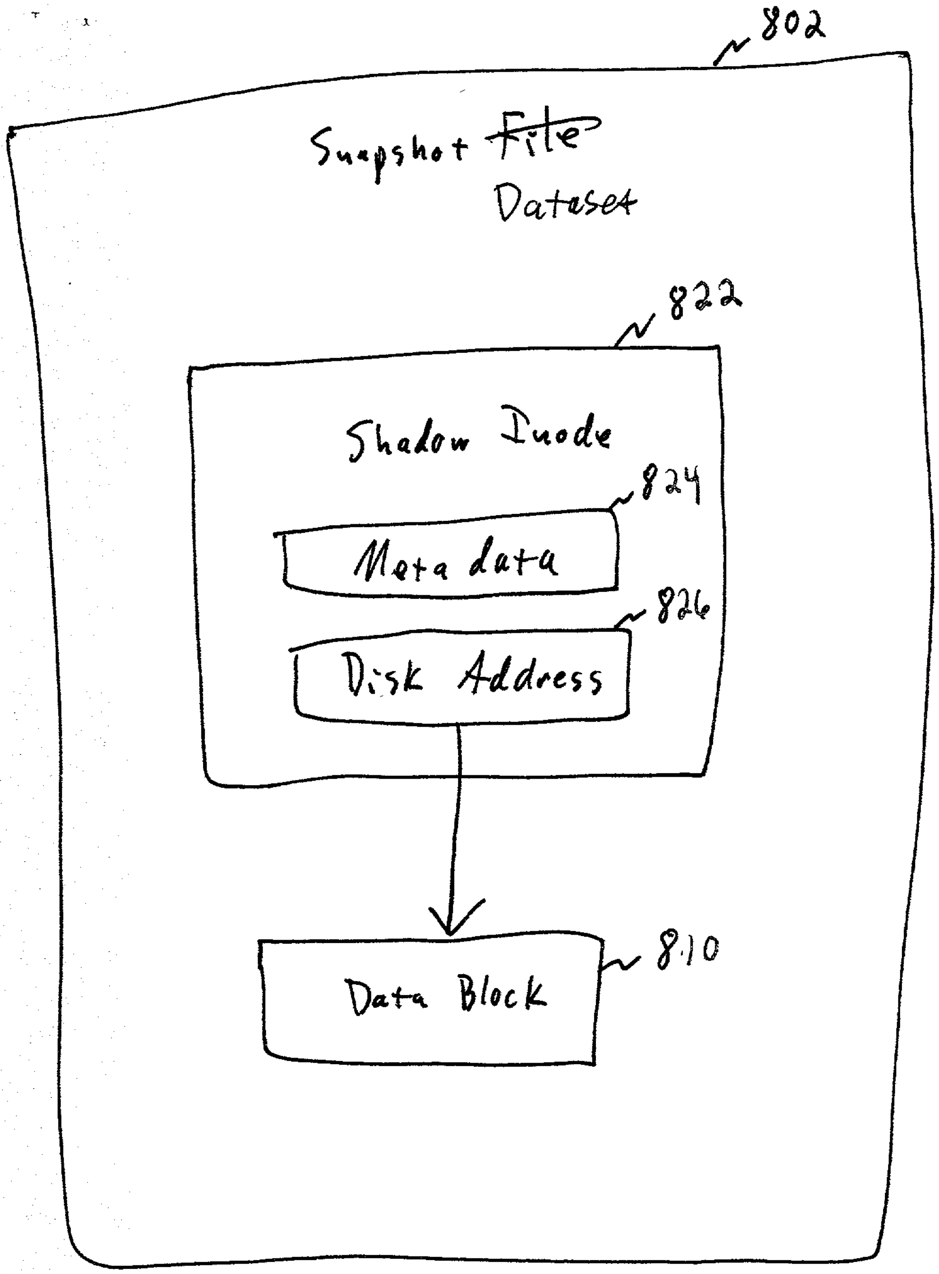

802
Snapshot ~~File~~ Dataset
822
Shadow Inode
824
Meta data
826
Disk Address
810
Data Block

FIG. 8C

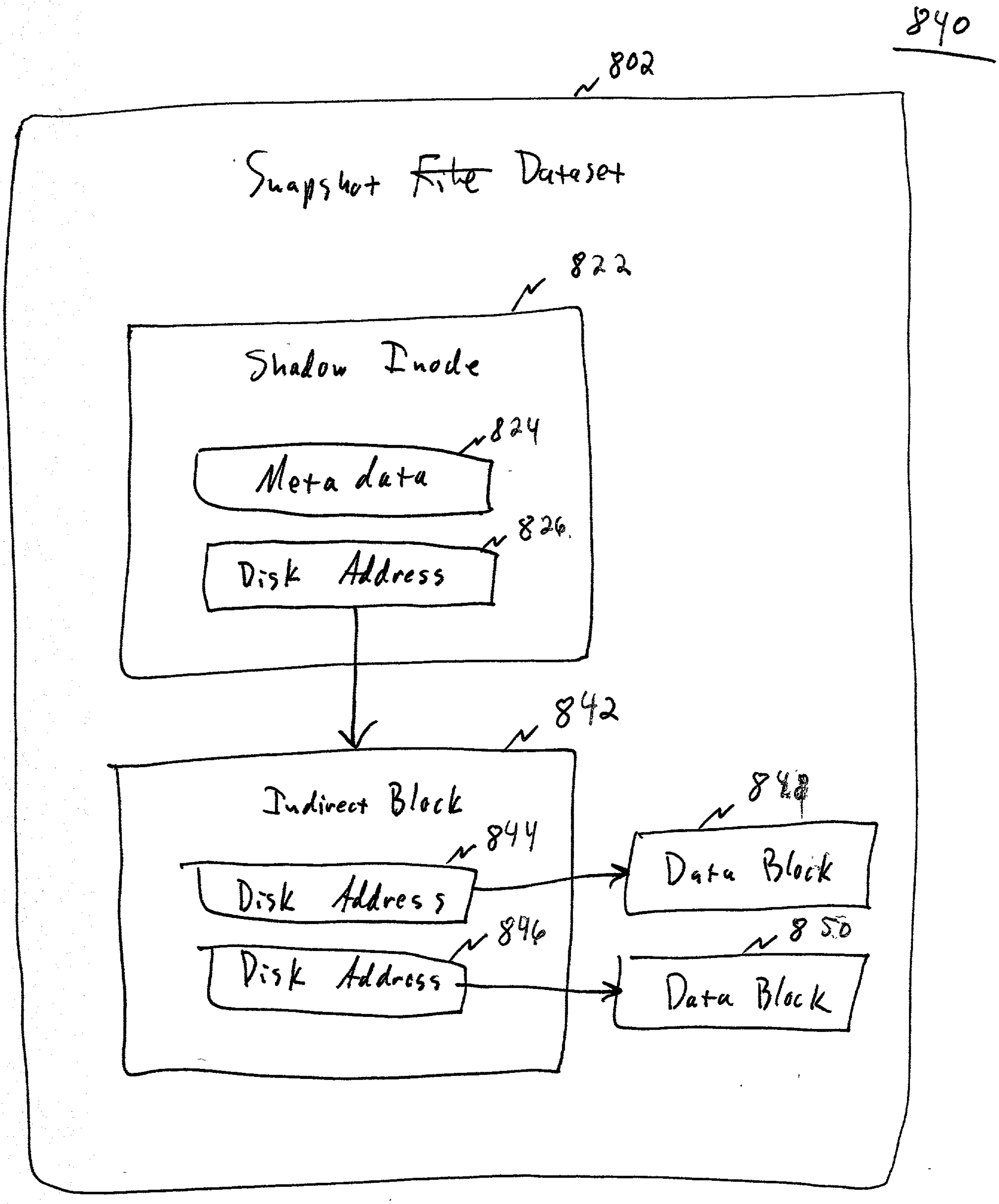

840
802
Snapshot ~~File~~ Dataset
822
Shadow Inode
824
Meta data
826
Disk Address
842
Indirect Block
844
Disk Address
846
Disk Address
848
Data Block
850
Data Block

FIG. 8D

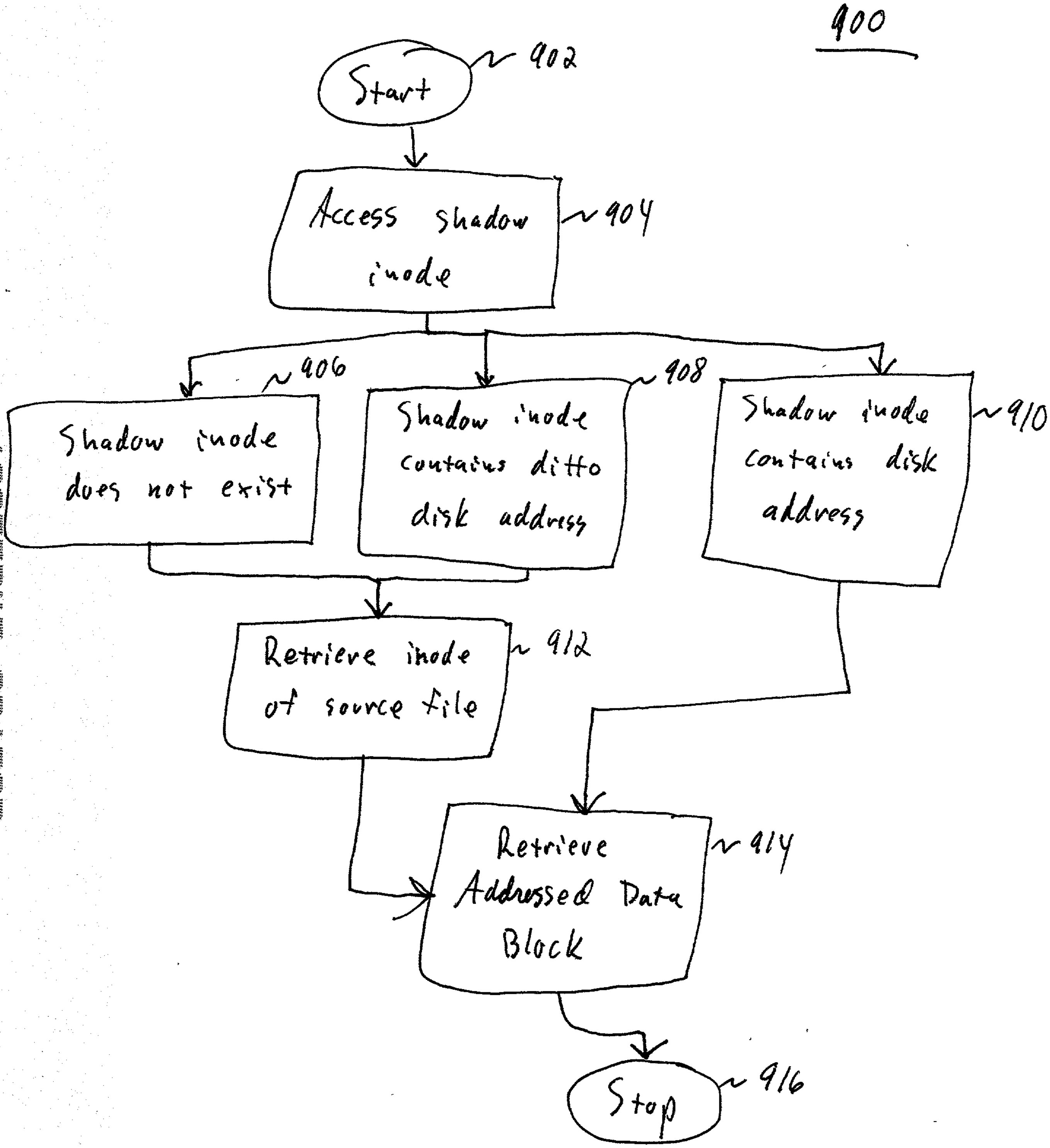

900
Start
902
Access shadow inode
904
906
Shadow inode does not exist
908
Shadow inode contains ditto disk address
Shadow inode contains disk address
910
Retrieve inode of source file
912
Retrieve Addressed Data Block
914
Stop
916

FIG. 9

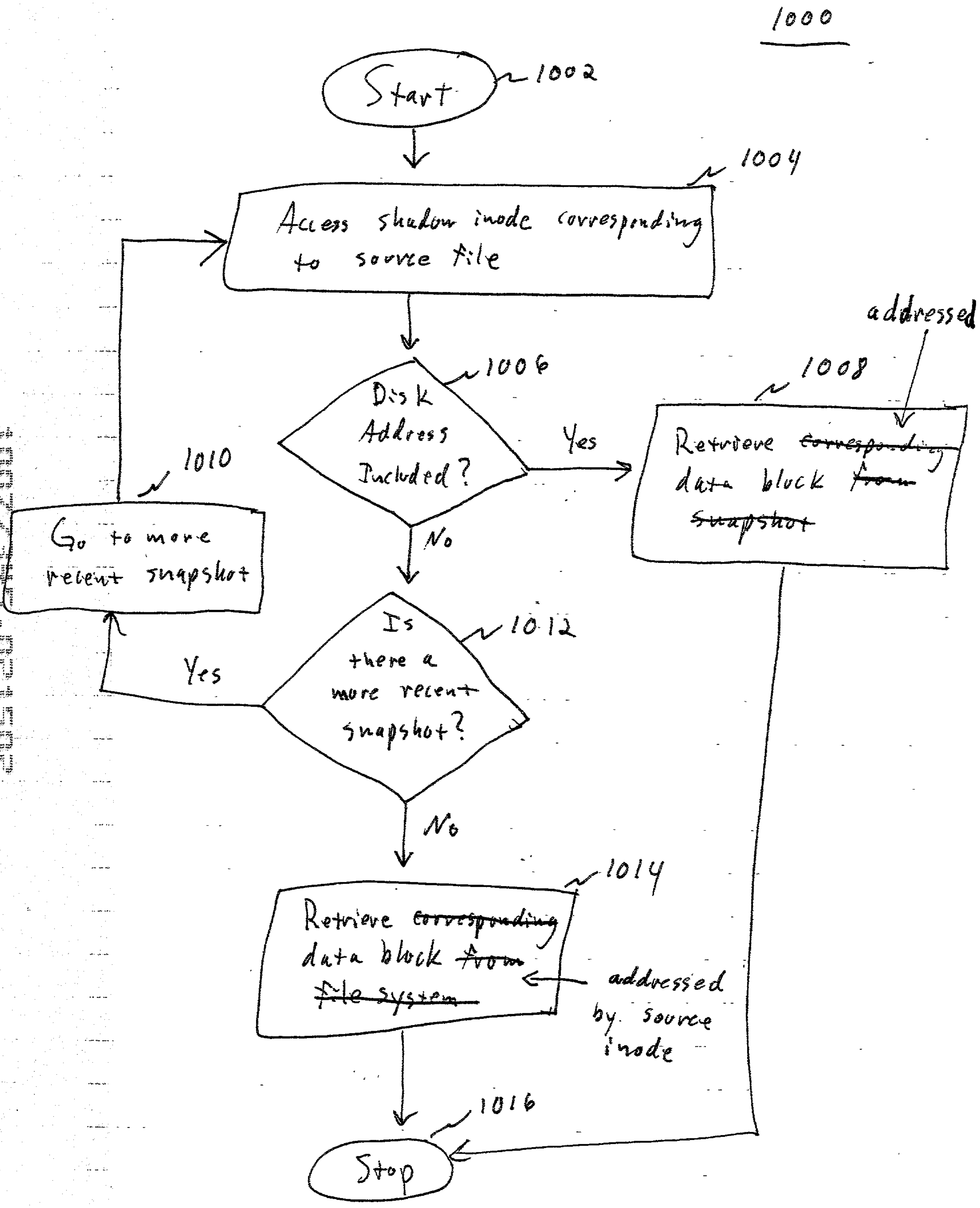

1000
Start
1002
Access shadow inode corresponding to source file
1004
Disk Address Included?
1006
Yes
Retrieve ~~corresponding~~ addressed data block ~~from snapshot~~
1008
No
Is there a more recent snapshot?
1012
Yes
Go to more recent snapshot
1010
No
Retrieve ~~corresponding~~ data block ~~from file system~~ addressed by source inode
1014
1016
Stop

FIG. 10

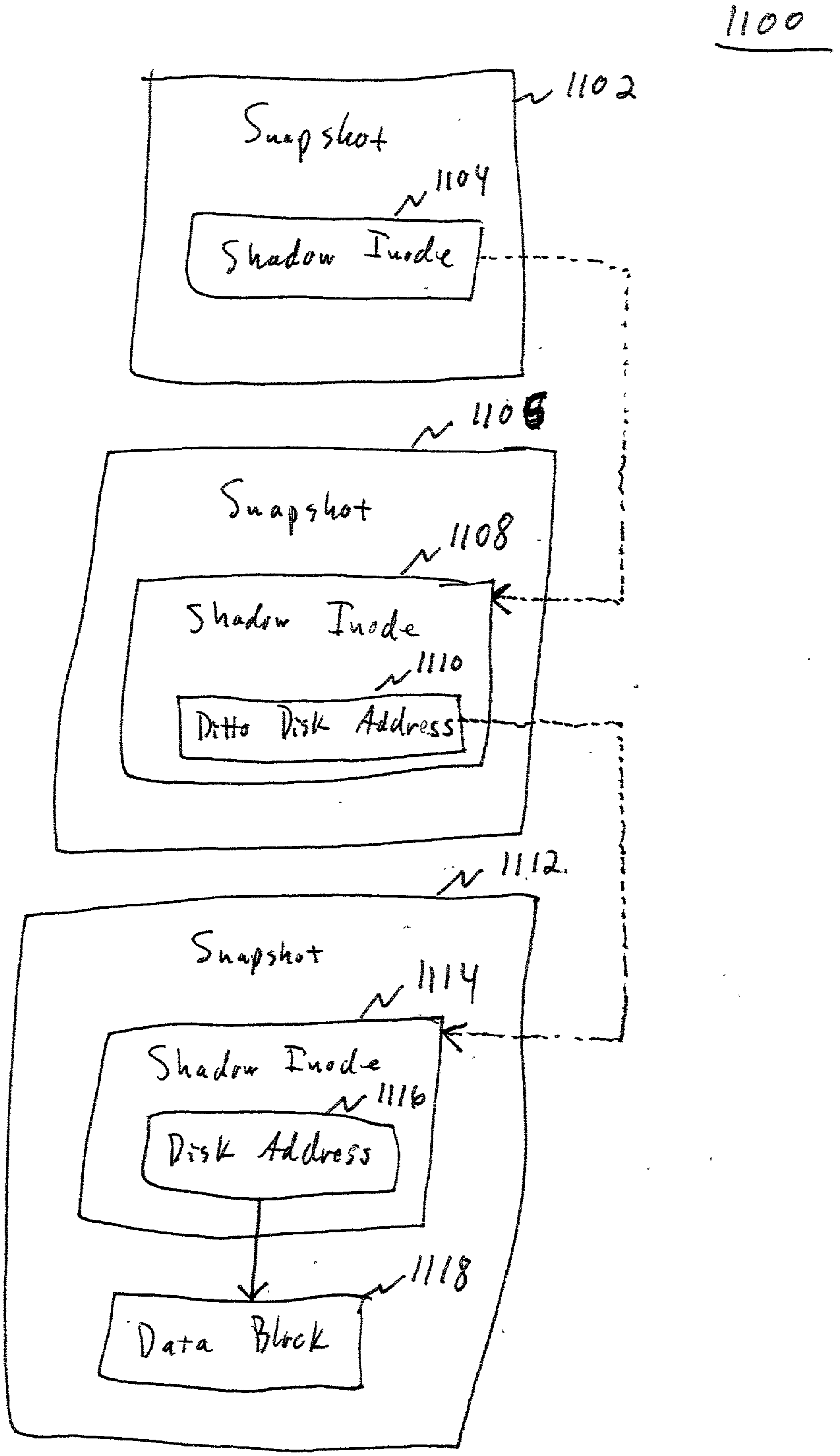

1100
1102
Snapshot
1104
Shadow Inode
1106
Snapshot
1108
Shadow Inode
1110
Ditto Disk Address
1112
Snapshot
1114
Shadow Inode
1116
Disk Address
1118
Data Block

FIG. 11

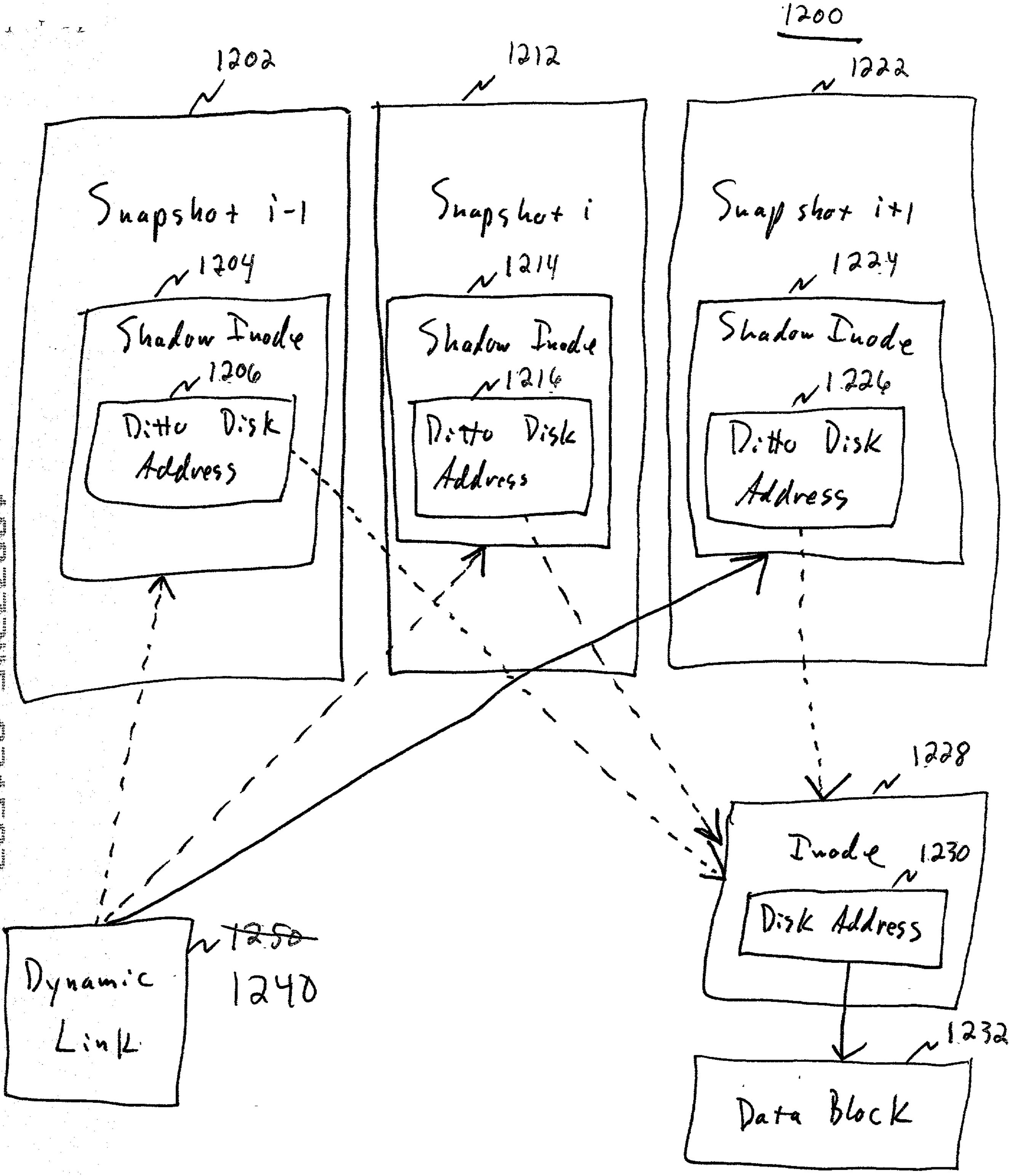

1200
1202
Snapshot i-1
1204
Shadow Inode
1206
Ditto Disk Address
1212
Snapshot i
1214
Shadow Inode
1216
Ditto Disk Address
1222
Snapshot i+1
1224
Shadow Inode
1226
Ditto Disk Address
1228
Inode
1230
Disk Address
1232
Data Block
Dynamic Link
~~1250~~
1240

FIG. 12A

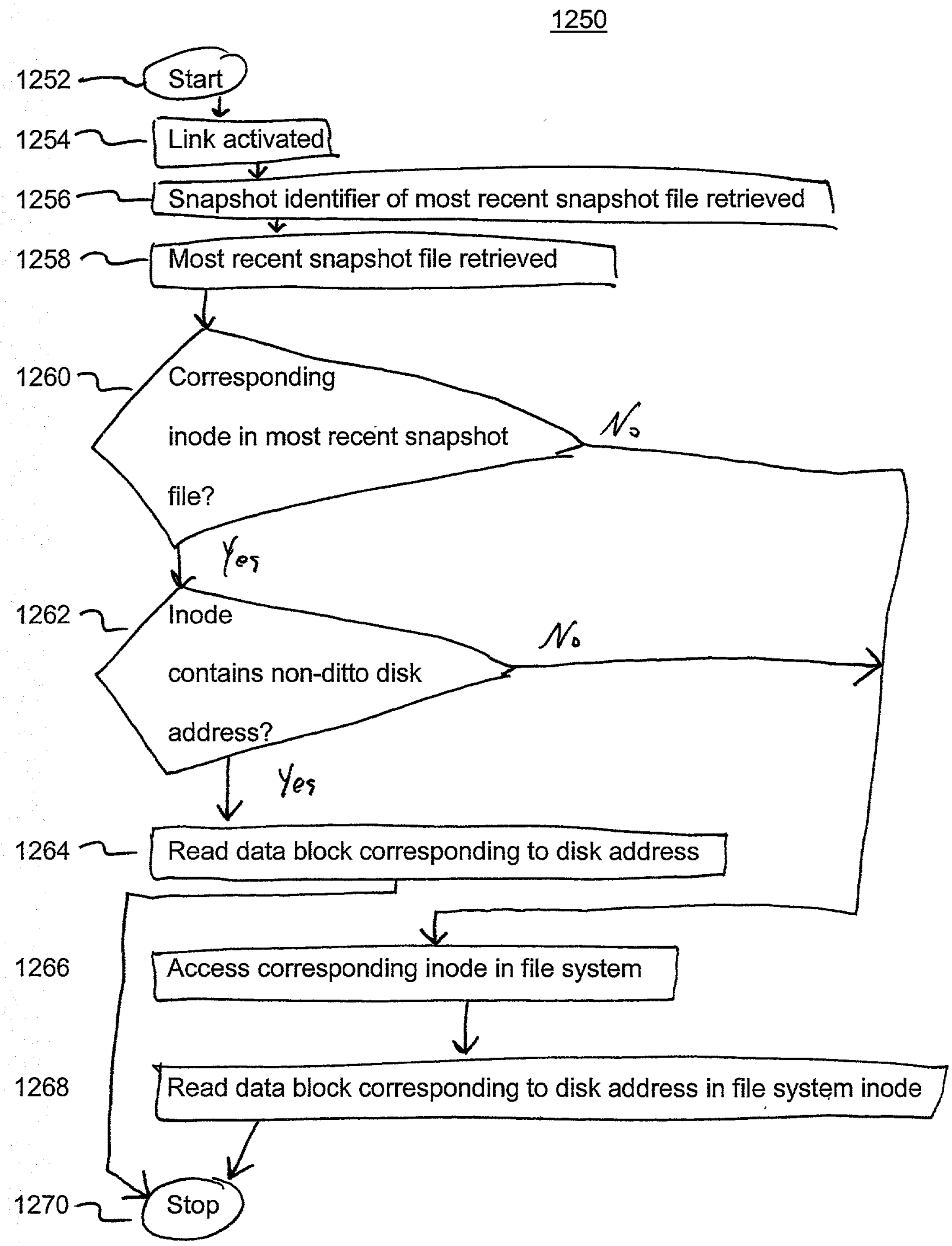

1250
1252
Start
1254
Link activated
1256
Snapshot identifier of most recent snapshot file retrieved
1258
Most recent snapshot file retrieved
1260
Corresponding inode in most recent snapshot file?
No
Yes
1262
Inode contains non-ditto disk address?
No
Yes
1264
Read data block corresponding to disk address
1266
Access corresponding inode in file system
1268
Read data block corresponding to disk address in file system inode
1270
Stop

FIG 12B

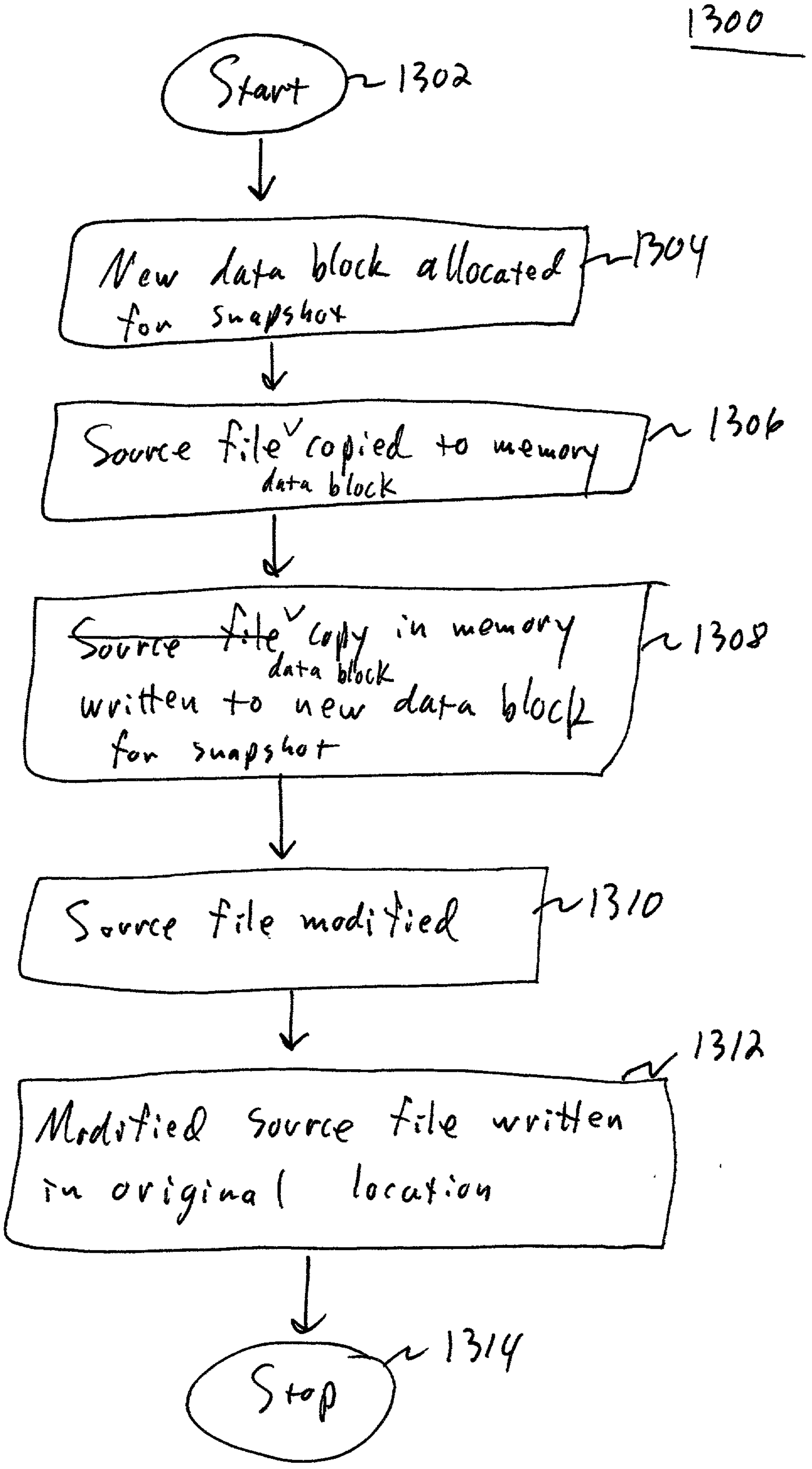

1300
Start
1302
New data block allocated for snapshot
1304
Source file data block copied to memory
1306
~~Source file~~ data block copy in memory written to new data block for snapshot
1308
Source file modified
1310
Modified source file written in original location
1312
Stop
1314

FIG. 13A

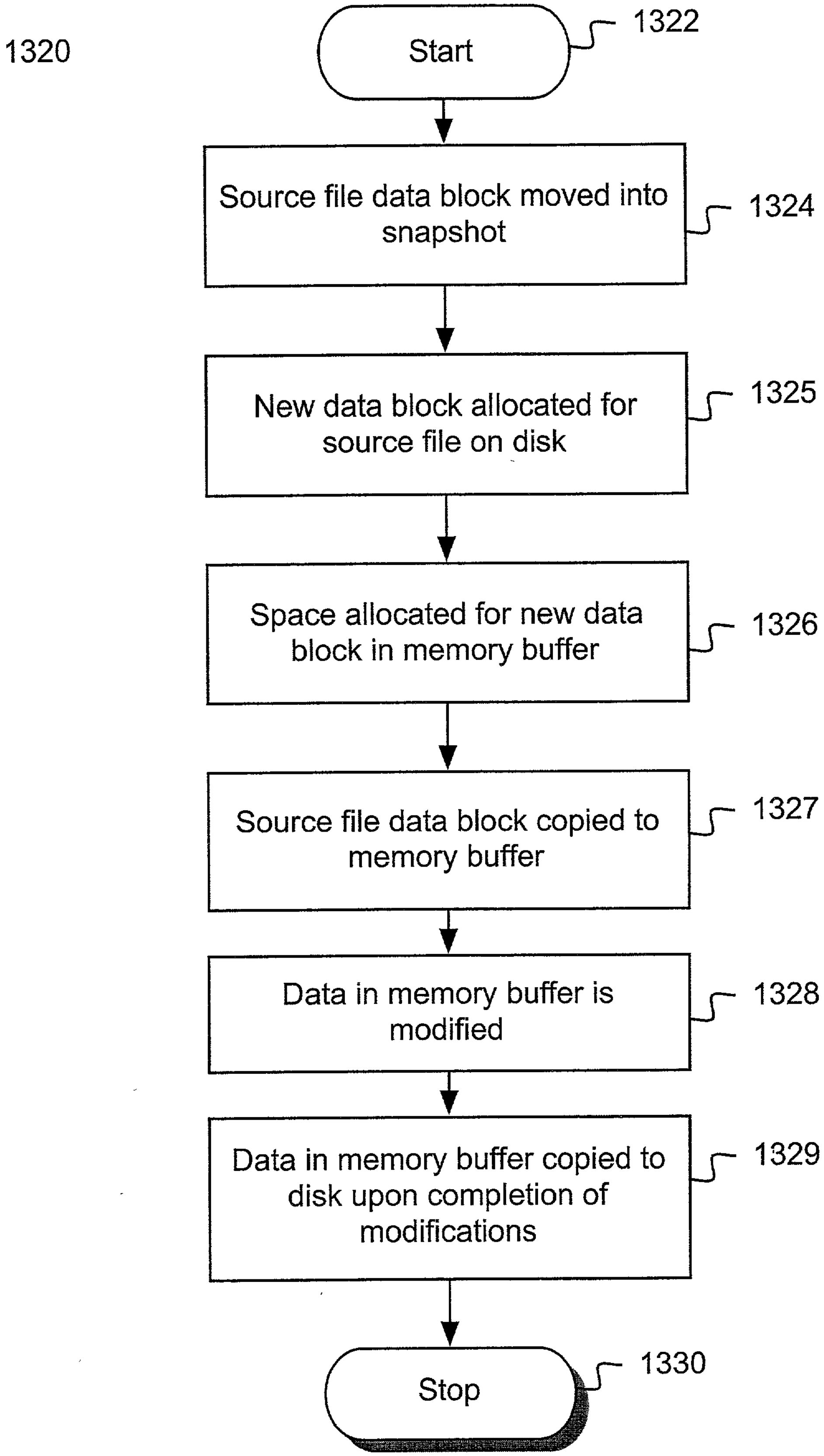

1320
Start
1322
Source file data block moved into snapshot
1324
New data block allocated for source file on disk
1325
Space allocated for new data block in memory buffer
1326
Source file data block copied to memory buffer
1327
Data in memory buffer is modified
1328
Data in memory buffer copied to disk upon completion of modifications
1329
Stop
1330

FIG 13B

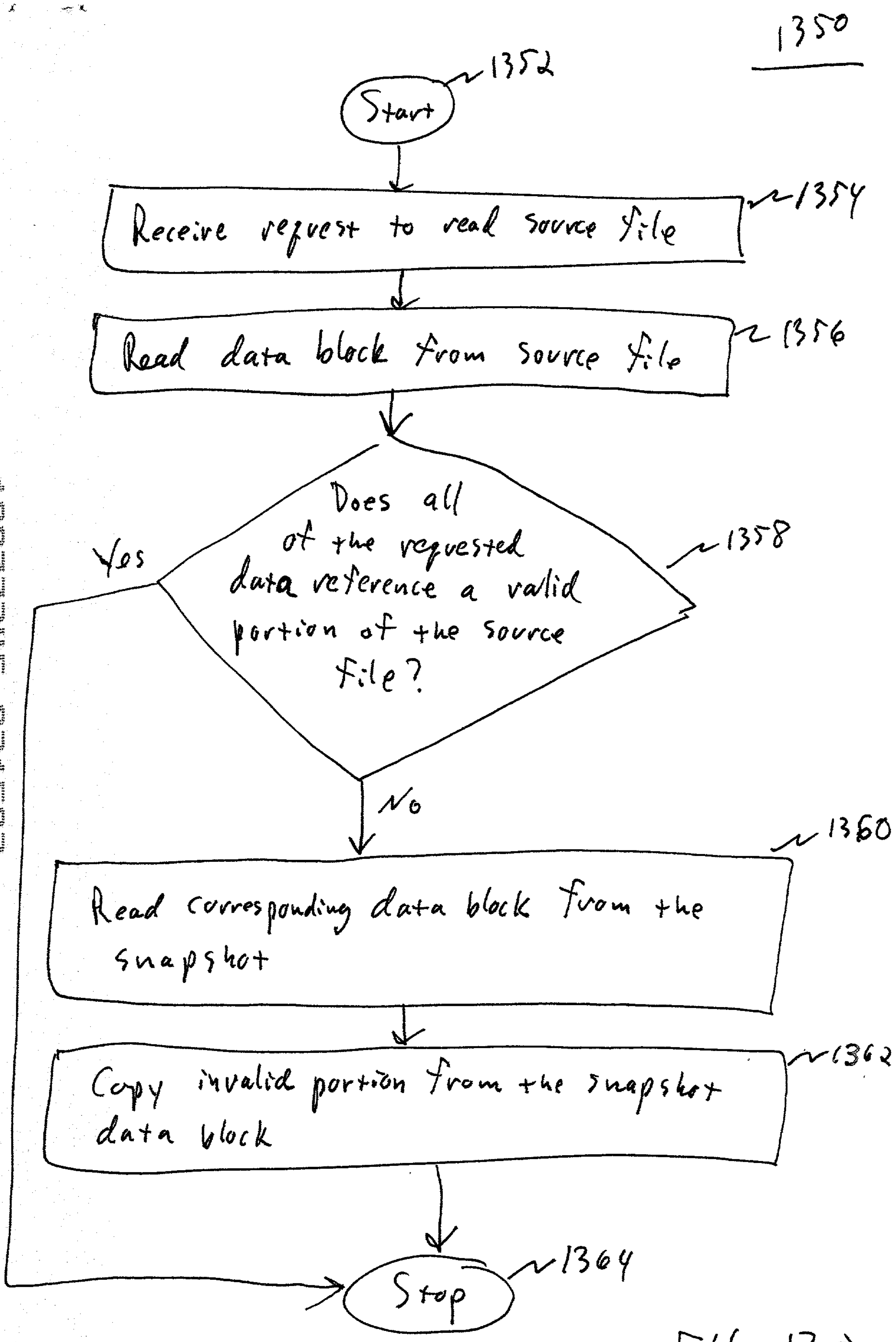

1350
Start
1352
Receive request to read source file
1354
Read data block from source file
1356
Does all of the requested data reference a valid portion of the source file?
1358
Yes
No
Read corresponding data block from the snapshot
1360
Copy invalid portion from the snapshot data block
1362
Stop
1364

FIG. 13C

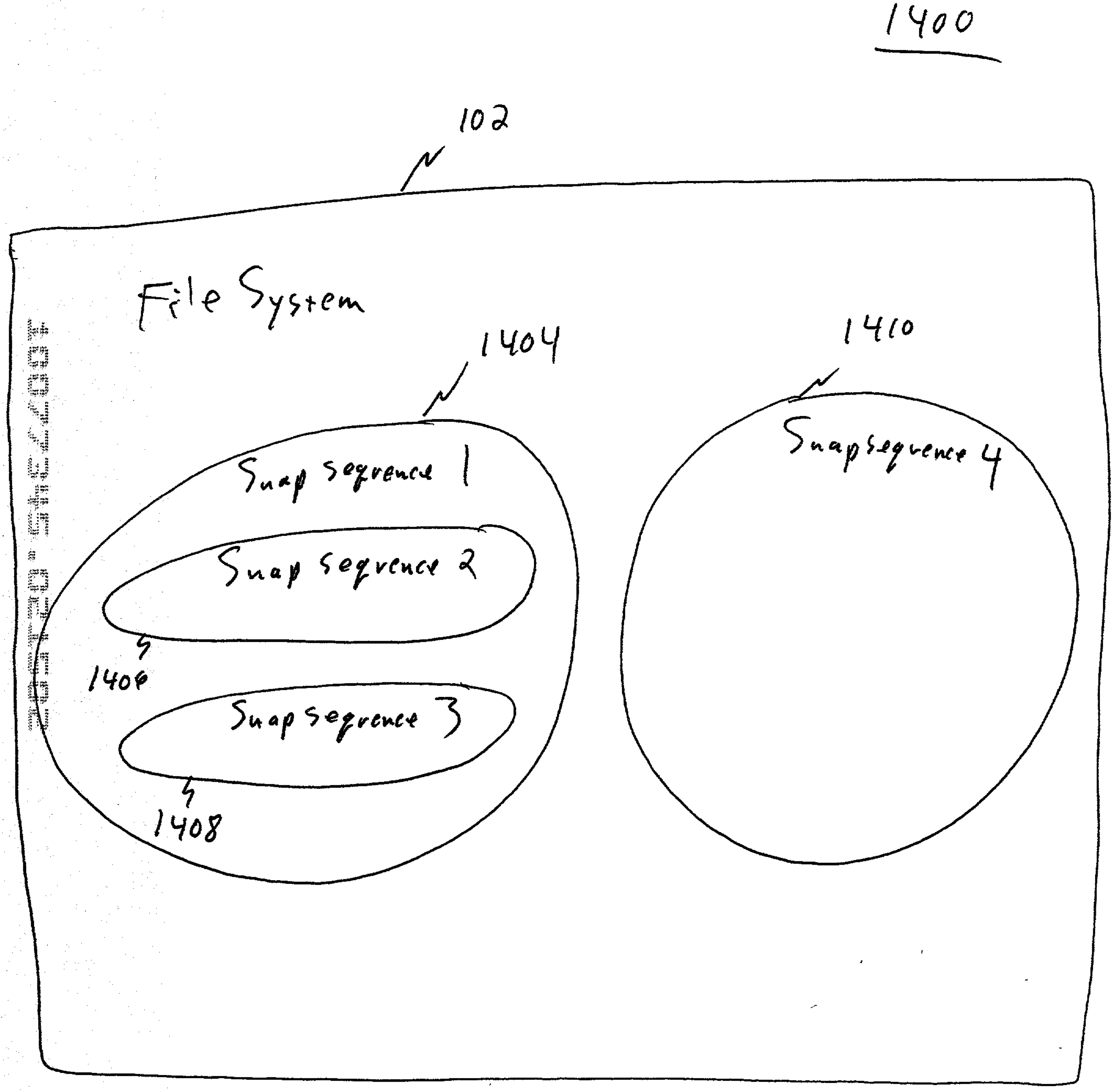

1400
102
File System
1404
Snap sequence 1
Snap sequence 2
1406
Snap sequence 3
1408
1410
Snapsequence 4

FIG. 14A

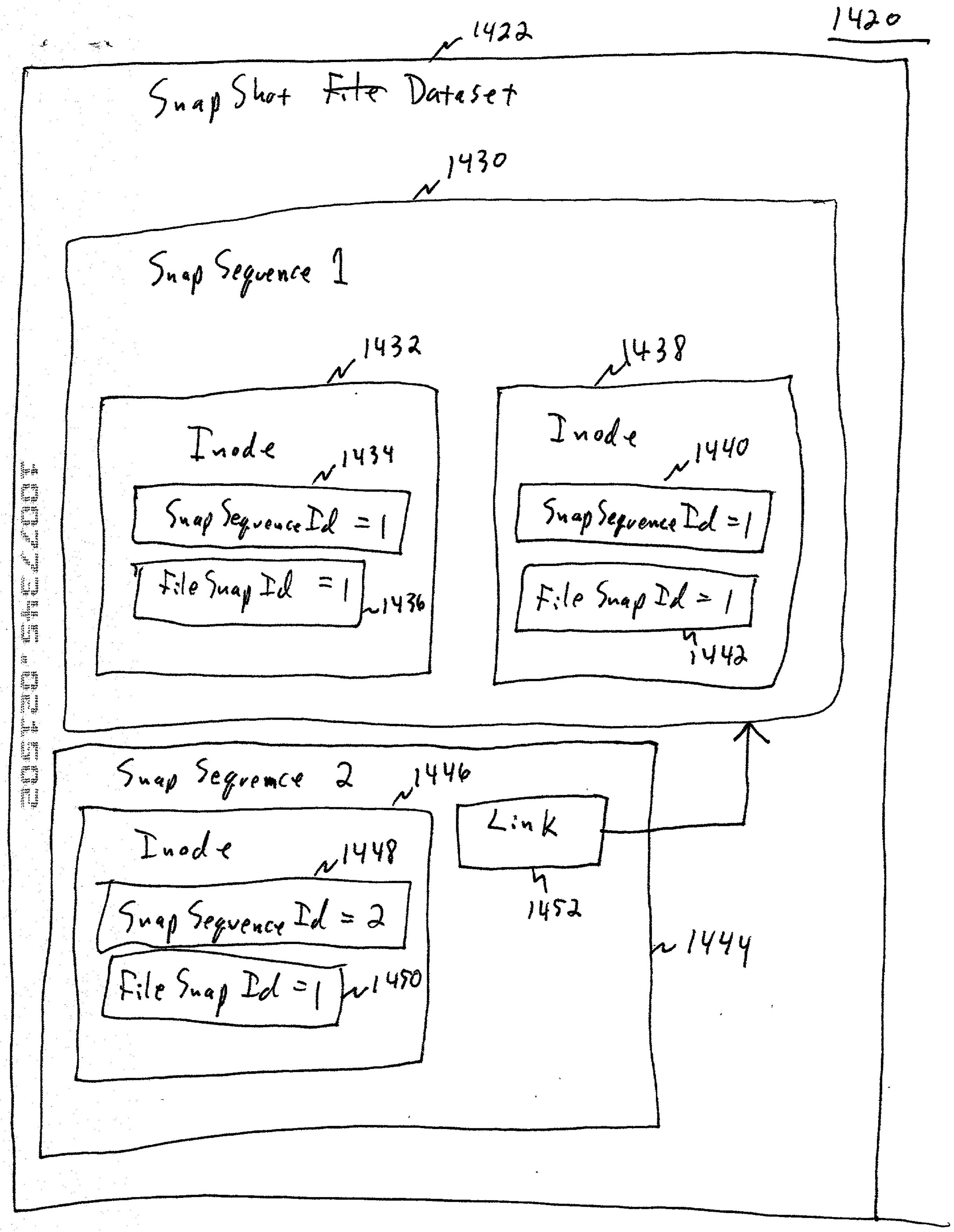

1420
1422
Snap Shot ~~File~~ Dataset
1430
Snap Sequence 1
1432
Inode
1434
Snap Sequence Id = 1
File Snap Id = 1
1436
1438
Inode
1440
Snap Sequence Id = 1
File Snap Id = 1
1442
Snap Sequemce 2
1446
Inode
1448
Snap Sequence Id = 2
File Snap Id = 1
1450
Link
1452
1444

FIG. 14B

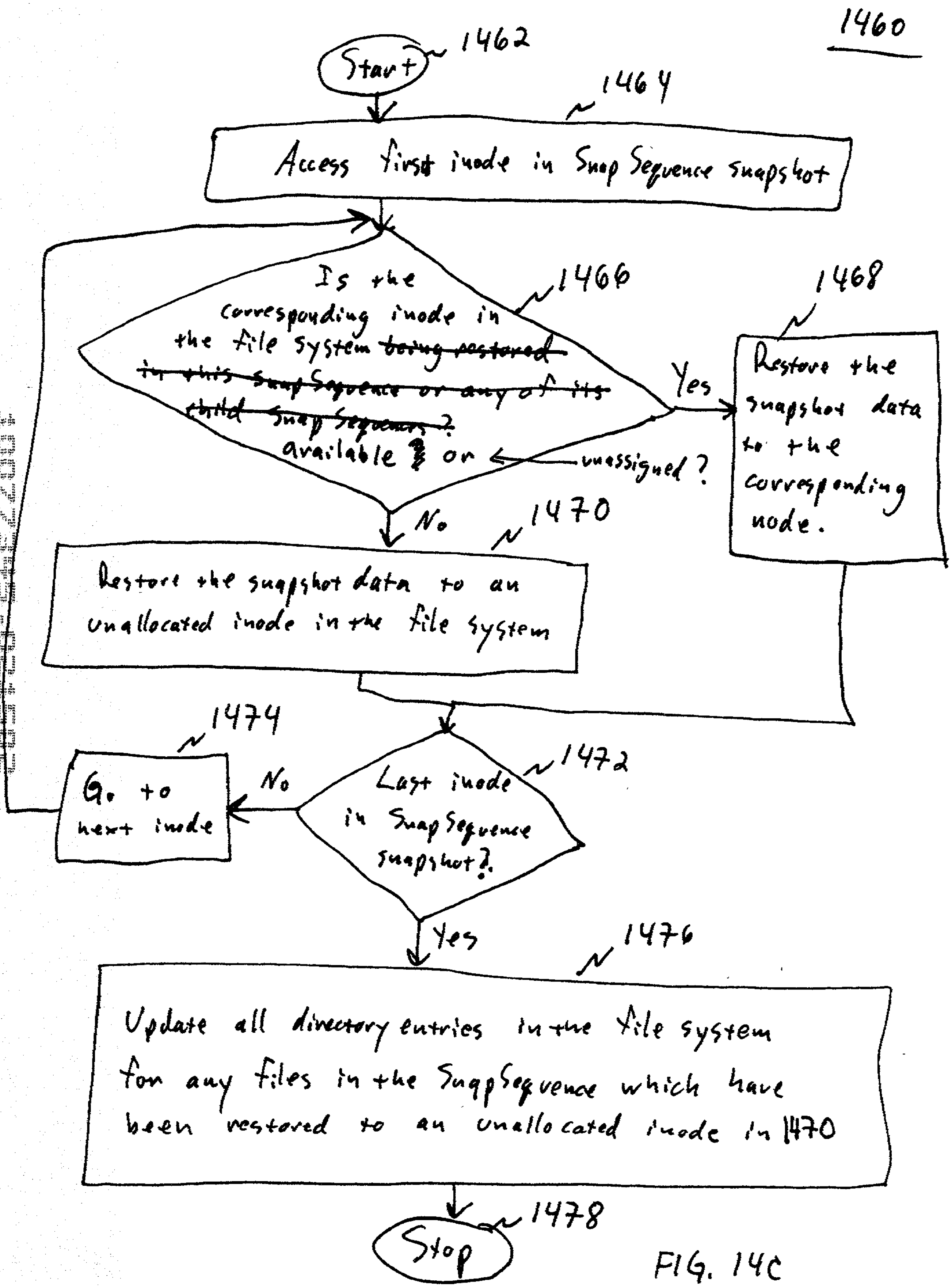

1460
Start
1462
1464
Access first inode in Snap Sequence snapshot
Is the corresponding inode in the file system ~~being restored in this SnapSequence or any of its child SnapSequences?~~ available? or unassigned?
1466
Yes
1468
Restore the snapshot data to the corresponding node.
No
1470
Restore the snapshot data to an unallocated inode in the file system
1474
Go to next inode
No
Last inode in SnapSequence snapshot?
1472
Yes
1476
Update all directory entries in the file system for any files in the SnapSequence which have been restored to an unallocated inode in 1470
Stop
1478

FIG. 14C

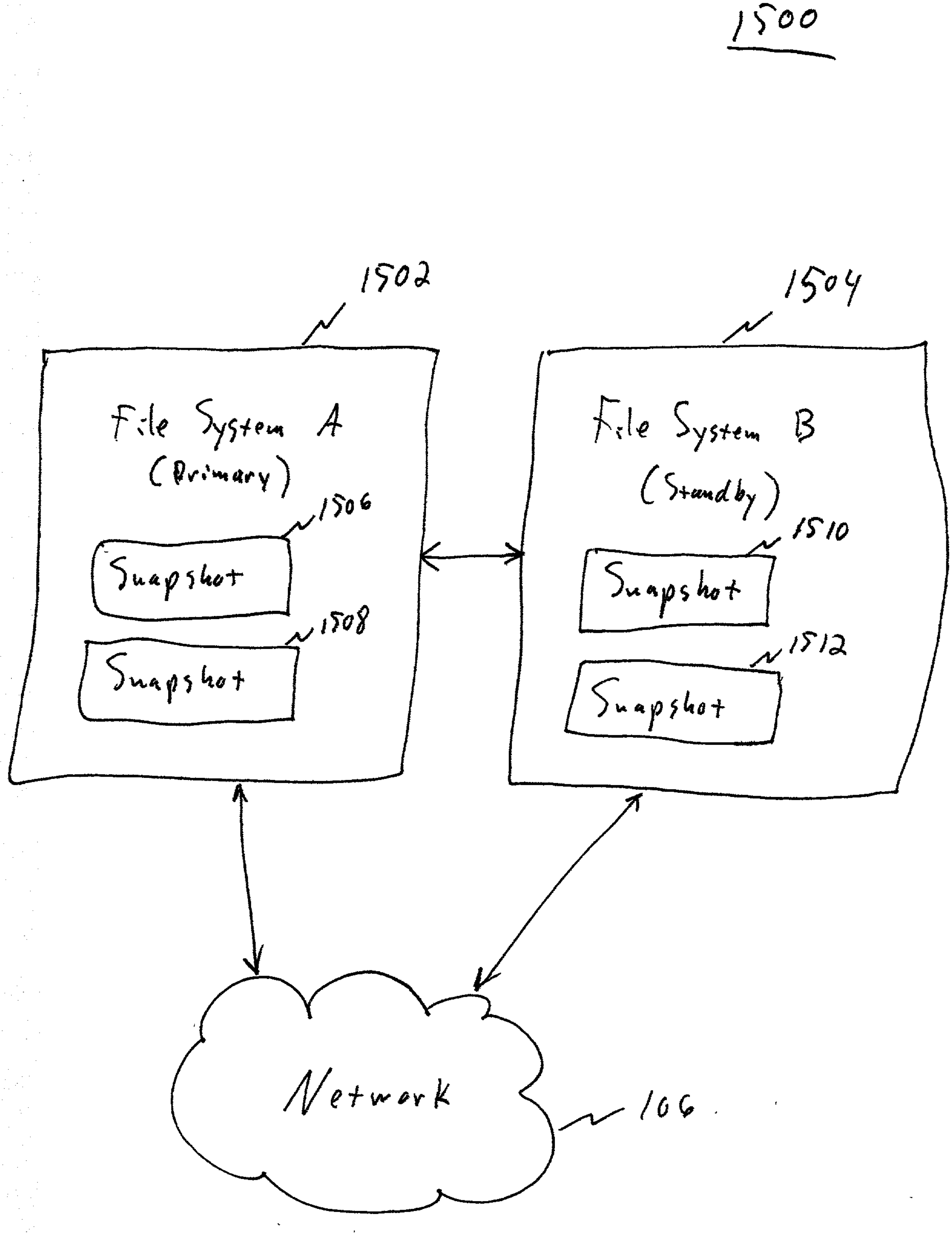

1500
1502
1504
File System A
(Primary)
File System B
(Standby)
1506
Snapshot
1508
Snapshot
1510
Snapshot
1512
Snapshot
Network
106

FIG. 15A

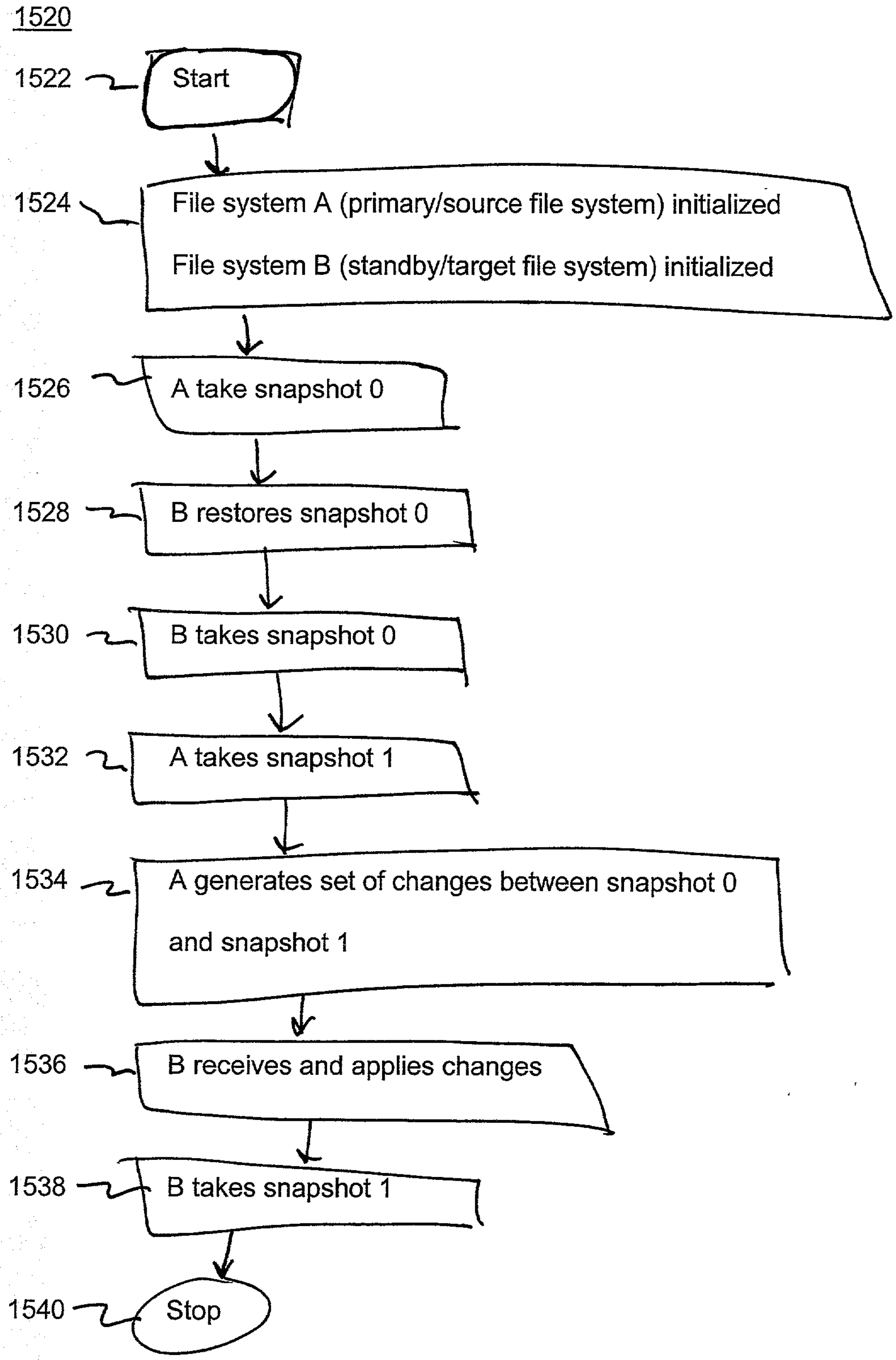

1520
1522
Start
1524
File system A (primary/source file system) initialized
File system B (standby/target file system) initialized
1526
A take snapshot 0
1528
B restores snapshot 0
1530
B takes snapshot 0
1532
A takes snapshot 1
1534
A generates set of changes between snapshot 0 and snapshot 1
1536
B receives and applies changes
1538
B takes snapshot 1
1540
Stop

FIG. 15B

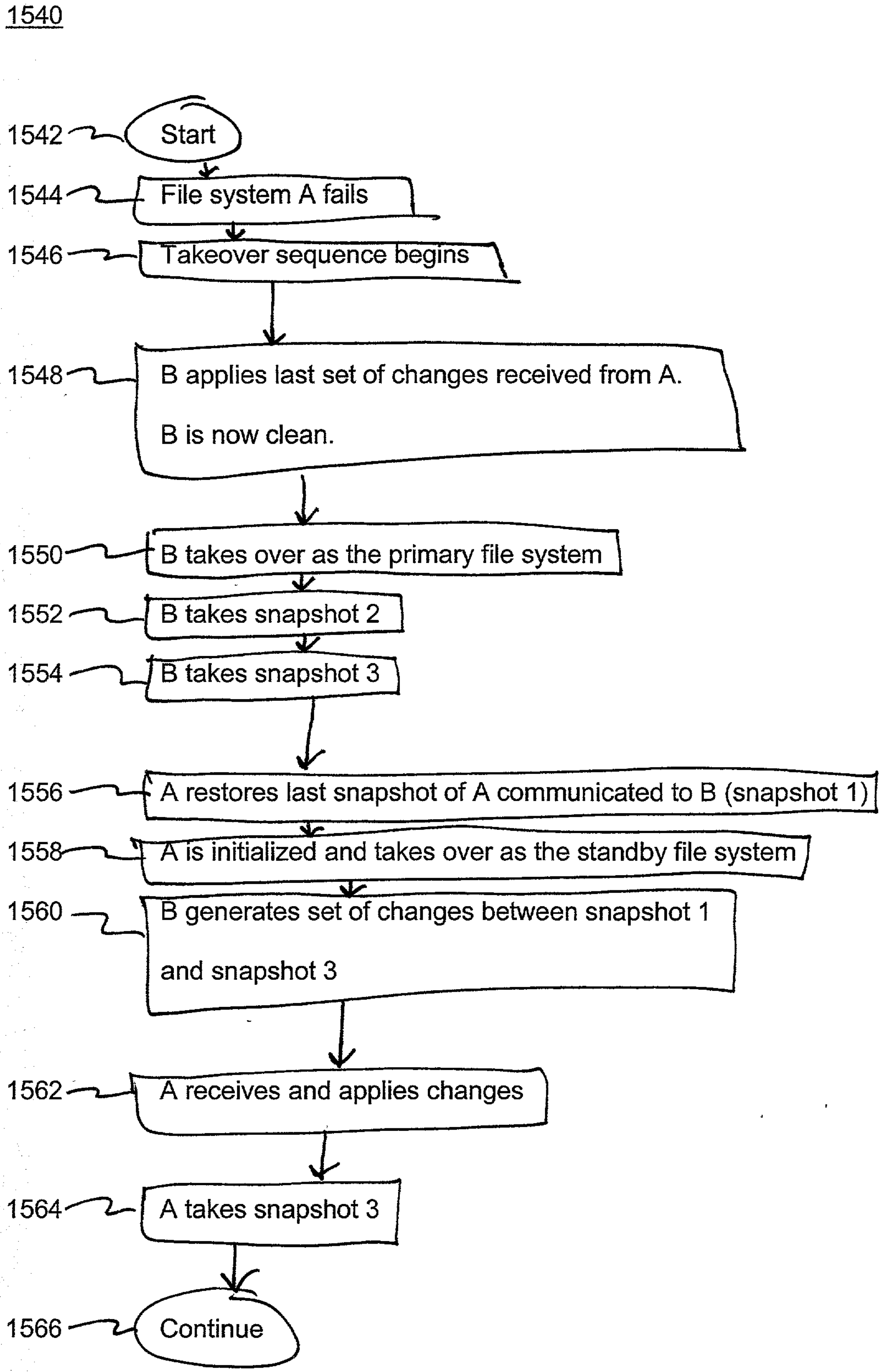

1540
1542
Start
1544
File system A fails
1546
Takeover sequence begins
1548
B applies last set of changes received from A.
B is now clean.
1550
B takes over as the primary file system
1552
B takes snapshot 2
1554
B takes snapshot 3
1556
A restores last snapshot of A communicated to B (snapshot 1)
1558
A is initialized and takes over as the standby file system
1560
B generates set of changes between snapshot 1 and snapshot 3
1562
A receives and applies changes
1564
A takes snapshot 3
1566
Continue

FIG. 15C

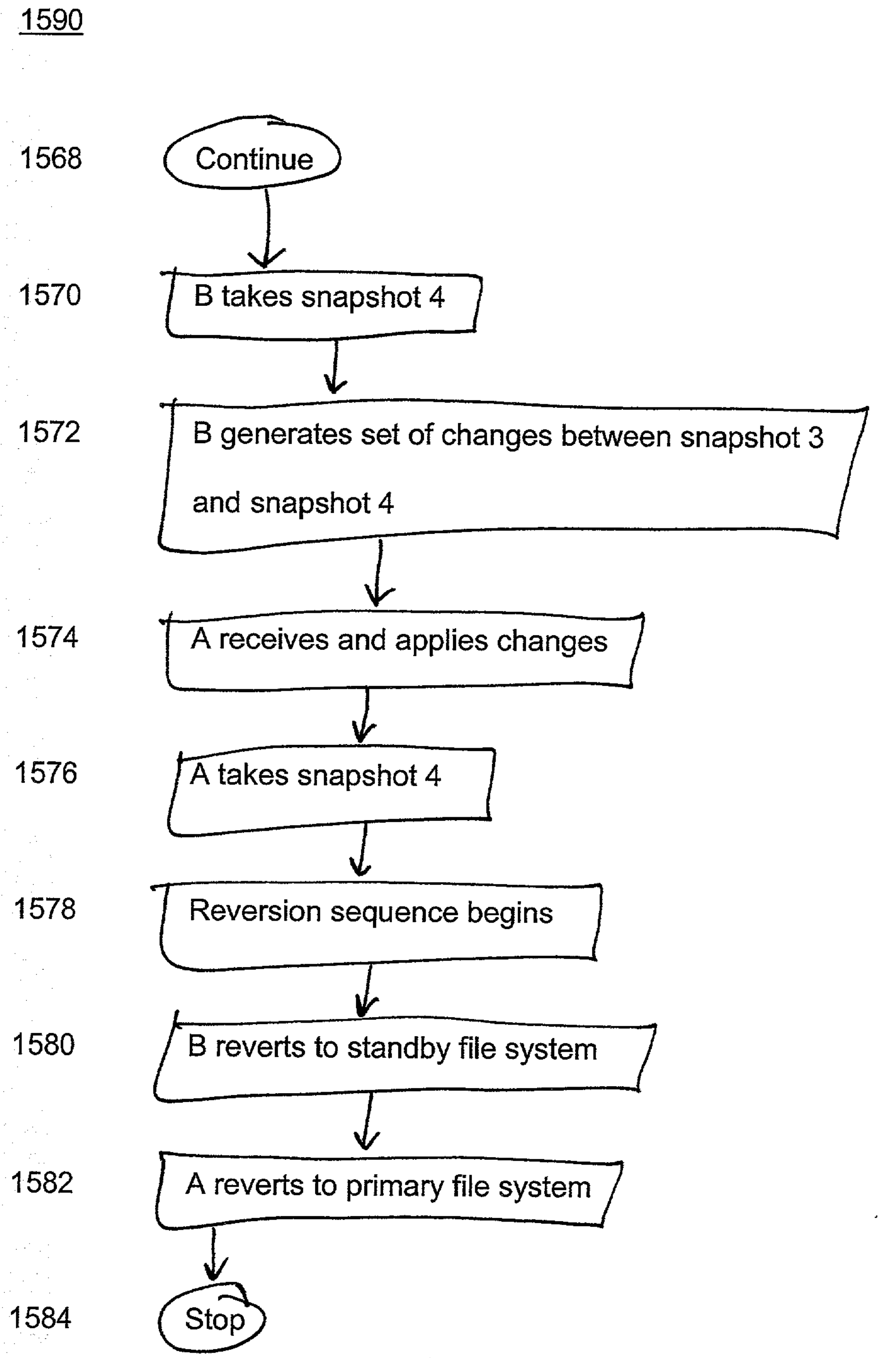
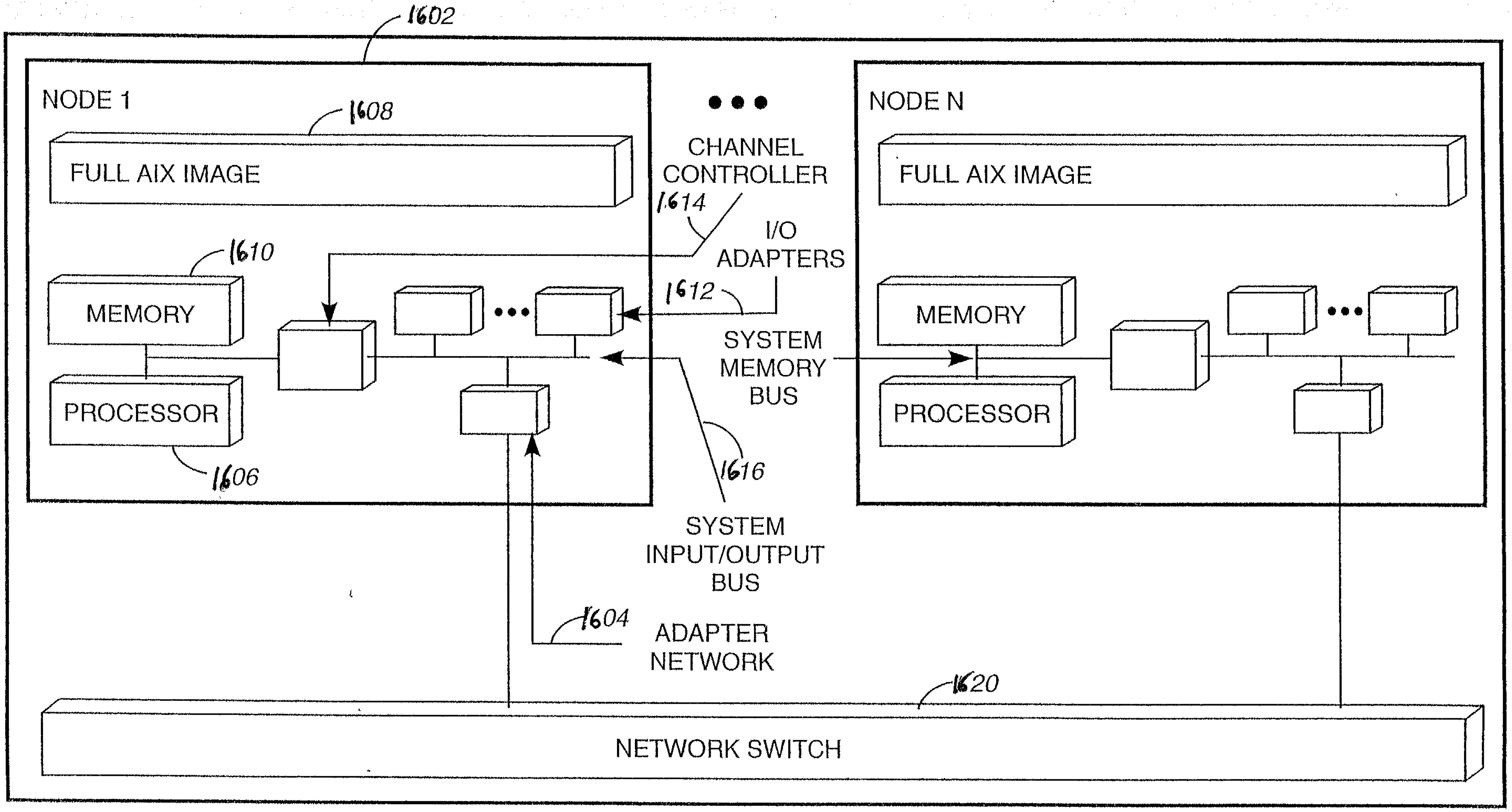

1590
1568
Continue
1570
B takes snapshot 4
1572
B generates set of changes between snapshot 3 and snapshot 4
1574
A receives and applies changes
1576
A takes snapshot 4
1578
Reversion sequence begins
1580
B reverts to standby file system
1582
A reverts to primary file system
1584
Stop

FIG. 15D


1602
NODE 1
1608
FULL AIX IMAGE
1610
MEMORY
PROCESSOR
1606
CHANNEL CONTROLLER
1614
I/O ADAPTERS
1612
SYSTEM MEMORY BUS
1616
SYSTEM INPUT/OUTPUT BUS
1604
ADAPTER NETWORK
NODE N
FULL AIX IMAGE
MEMORY
PROCESSOR
1620
NETWORK SWITCH

1600

FIG. 16

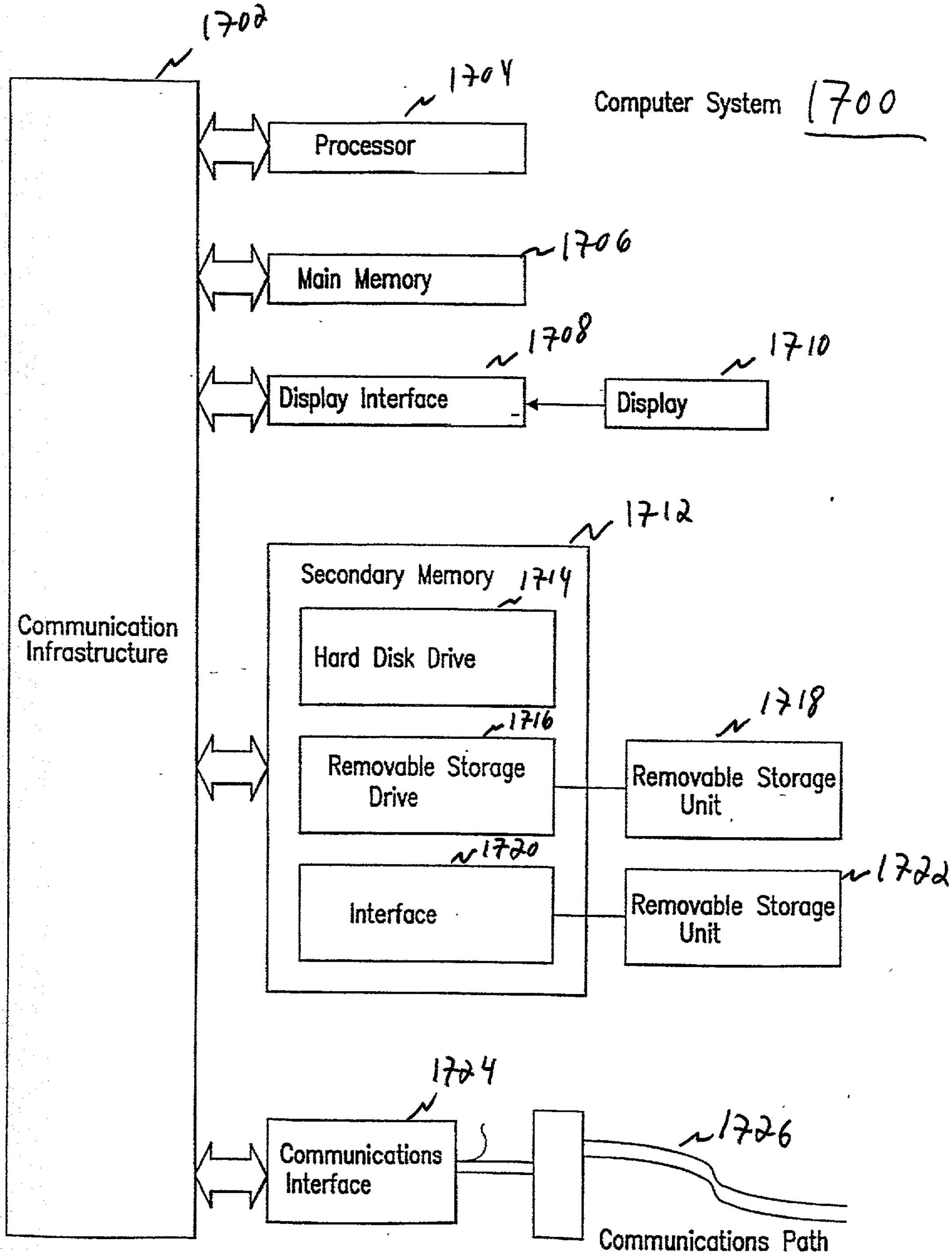

1702
1704
Computer System 1700
Processor
Main Memory
1706
1708
1710
Display Interface
Display
1712
Secondary Memory
1714
Hard Disk Drive
Communication Infrastructure
1716
1718
Removable Storage Drive
Removable Storage Unit
1720
1722
Interface
Removable Storage Unit
1724
1726
Communications Interface
Communications Path

FIG. 17